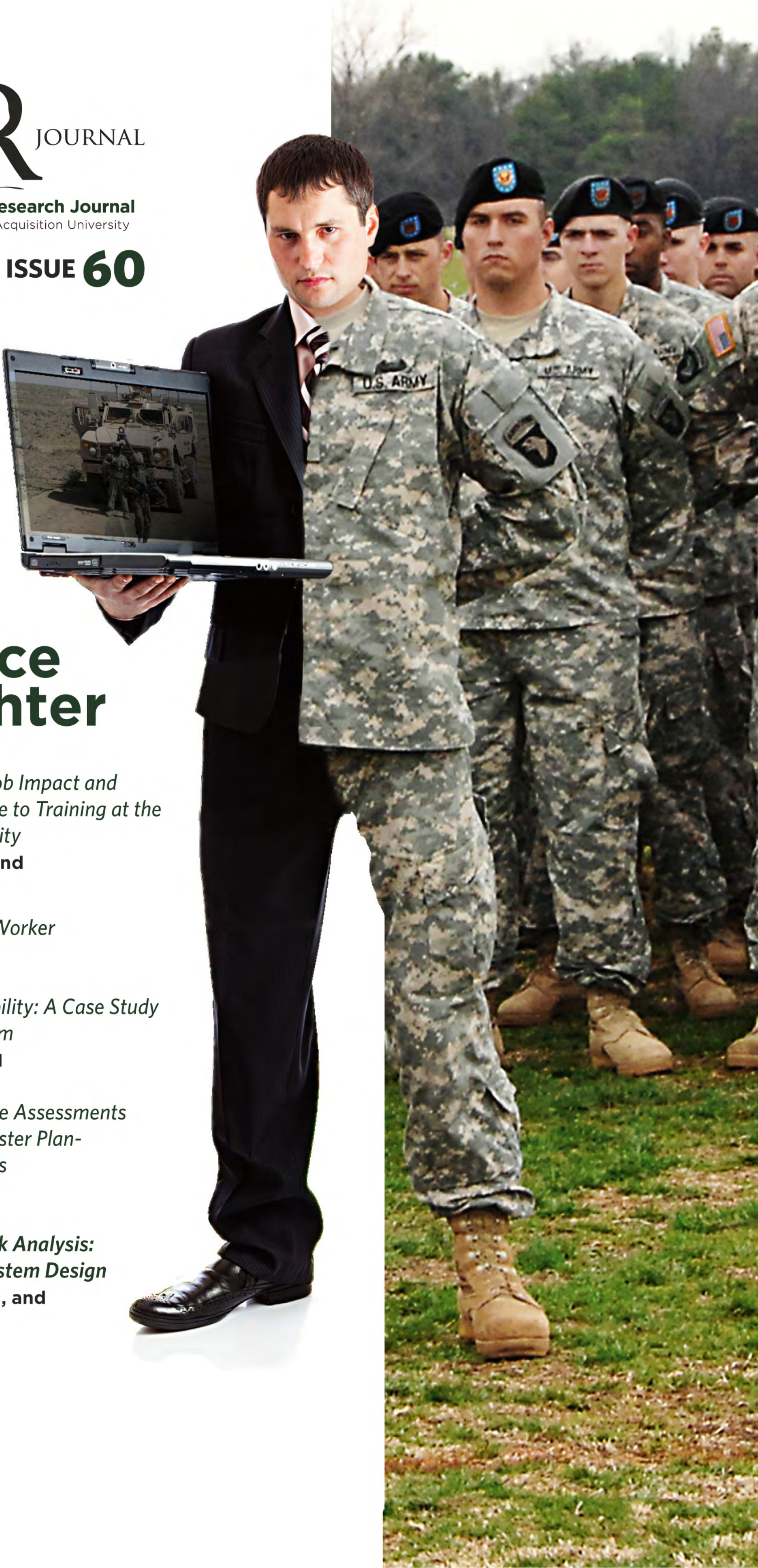
DEFENSE AR JOURNAL

Defense Acquisition Research Journal
A Publication of the Defense Acquisition University

October 2011 Vol. 18 No. 4 | **ISSUE 60**



From **Workforce** to **Warfighter**

Defense Acquisition University

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **OCT 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **Defense Acquisition Research Journal**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defense Acquisition University Press,9820 Belvoir Rd, Suite 3,Fort Belvoir,VA,22060**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Defense Acquisition Research Journal, October 2011, vol 18, No. 4, Issue 60

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**135**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Defense Acquisition University

ISSN 2156-8391 (print) ISSN 2156-8405 (online)

The *Defense Acquisition Research Journal*, formerly the *Defense Acquisition Review Journal*, is published quarterly by the Defense Acquisition University (DAU) Press. Postage is paid at the U.S. Postal facility, Fort Belvoir, VA, and at additional U.S. Postal facilities. Postmaster, send address changes to: Editor, *Defense Acquisition Research Journal*, DAU Press, 9820 Belvoir Road, Suite 3, Fort Belvoir, VA 22060-5565. For free copies, mail written requests with an original signature to the above address using the subscription form provided in this journal. Some photos appearing in this publication may be digitally enhanced. Articles represent the views of the authors and do not necessarily reflect the opinion of DAU or the Department of Defense.

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DEFENSE ARJ JOURNAL

Defense Acquisition Research Journal
A Publication of the Defense Acquisition University

The ***Defense Acquisition Research Journal (ARJ)*** is a scholarly peer-reviewed journal published by the Defense Acquisition University (DAU). All submissions receive a blind review to ensure impartial evaluation.

TABLE OF CONTENTS

DEFENSE ACQUISITION RESEARCH JOURNAL

October 2011 Vol. 18 No. 4 | **ISSUE 60**

The Defense Acquisition University (DAU) is an integral component in the career of every Defense Acquisition Workforce member, from the time they enroll in their first DAU course until they retire. One of the many keys to DAU's success is its ability to measure the effectiveness of its training programs, monitor performance, and improve its curriculum. To this end, the authors conducted a data mining exercise within the training evaluation data to determine the key drivers of its success. This article explains the methodological approach used (structural equation modeling) as well as the results, recommended actions, and outcomes. Within the DAU learning enterprise, more than 326,000 training events were evaluated during 19 months between January 1, 2008, and July 30, 2009. Results indicate that DAU's learning enterprise positively influences job impact and business results.

Commonly accepted economic theory suggests that workers are rational actors and make decisions that will maximize expected outcomes. As such, managers should be able to influence behaviors to meet business goals by manipulating the expectations of outcomes. Conversely, social science practitioners suggest that workers often make decisions that are irrational. Knowledge workers are a growing sector of the workforce and are the backbone for entire federal agencies. The acquisition community falls within this category. Identifying factors that influence the performance of knowledge workers may be critical to maintaining high levels of organizational performance. This research focused on identifying the factors that encourage knowledge workers to maintain high levels of performance.

Most government and industry leaders involved with Department of Defense acquisition programs emphasize the importance of requirements and cost stability. However, despite all the stated support for program element stability and acquisition reform, frequent changes are experienced in acquisition programs that affect the final end product in terms of changes to unit design, number of units procured, system and subsystem capability, as well as affecting the overall cost of the program. This study analyzes the U.S. Navy's F/A-18A model to identify requirements changes; discern the reasons for change and the impact the resultant change made on the program (funding, schedule, capacity, etc.); and develop recommendations for limiting requirements creep, instability, and cost growth in future programs.

The integrated master plan (IMP) provides a better structure than either the work breakdown structure (WBS) or organizational breakdown structure for measuring actual integrated master schedule (IMS) progress. The author posits that improved understanding of schedule performance and better identification of program risks result when an IMP structure is evaluated in addition to the earned value management-mandated IMS WBS structure. The article examines how the "Hit-Miss" index, baseline execution index, and critical path length index (CPLI) were used to evaluate the life-cycle performance of a 12-month, 900-task IMP program event. CPLI, the author concludes, is subject to interpretation and must be evaluated against four caveats: duration remaining, total float including schedule margin, schedule compression, and schedule avoidance.

TABLE OF CONTENTS

DEFENSE ACQUISITION RESEARCH JOURNAL

October 2011 Vol. 18 No. 4 | **ISSUE 60**

Today's warfighter performs more complex, cognitively demanding tasks than ever before. Despite the need for more extensive training to perform these tasks, acquisition professionals are often tasked to reduce training budgets and identify optimal tradeoffs. Tools are available to help them make these decisions that provide empirical evidence of how performance and mission requirements will be affected by design decisions. This article offers insights into the utility of implementing a Workload Task Analysis (WLTA) early in weapon systems acquisition for the purpose of focusing on training system decisions, and provides a description of where WLTA occurs within the top-down functional analysis process. It concludes with several examples of how the WLTA results can be used to guide training development.

NEWS YOU CAN USE

We are currently soliciting articles and subject matter experts for the 2012 *Defense Acquisition Research Journal (ARJ)* print year.

DEFENSE AR JOURNAL

Defense Acquisition Research Journal

A Publication of the Defense Acquisition University

From Workforce to Warfighter

Cover image designed by Harambee Dennis »

FROM THE CHAIRMAN AND EXECUTIVE EDITOR

"From Workforce to Warfighter" describes the end-to-end process of developing our nation's defense capabilities. It begins long before a user requirement is ever written—in the hiring, training, and retention of our Defense Acquisition Workforce. It continues long after a system or service is produced—in the hands and mind of the warfighter downrange.

The first two articles deal with the Defense Acquisition Workforce. Nick Bontis, Chris Hardy, and John Mattox demonstrate how effective training of this workforce contributes to improvements in job performance and business results. David Frick, in his article, argues that in order to keep this workforce (primarily composed of "knowledge workers") motivated, traditional approaches such as pay-for-performance are increasingly anachronistic and may need to be discarded, while more nontraditional approaches need to be examined.

The next two articles take to task long-held assumptions about the defense acquisition process. Jay Bottelson examines the Navy's F/A-18 Hornet program in terms of requirements creep and cost growth, and finds that the problems occurred in unexpected ways. David Bachman argues that using integrated master plans provides more meaningful metrics for measuring near-term schedule performance than the traditional management tools of work and organizational breakdown structures. Finally, Dennis Duke, Dana Sims, and James Pharmer take us downrange, discussing how workload task analysis can help the decision-making process for developing warfighter training systems.

The latest addition to the Defense Acquisition Professional's Reading List is Neil Sheehan's comprehensive look at the cold war development of the Intercontinental Ballistic Missile, *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon*, reviewed here by James Dobbins.

Please take note of two Calls for Papers:

1. "Doing More without More: Government and Industry Imperatives for Achieving Acquisition Efficiencies," Defense Acquisition University Alumni Association 2012 Hirsch Research Paper Competition, which will

take place at the DAU main campus, Fort Belvoir, Virginia, in April 2012. Please submit papers by November 1, 2011.

2. "The Limits of Competition in Defense Acquisition" Research Symposium, which will also take place at the DAU main campus, Fort Belvoir, Virginia, September 18–19, 2012. Please submit abstracts by November 30, 2011.

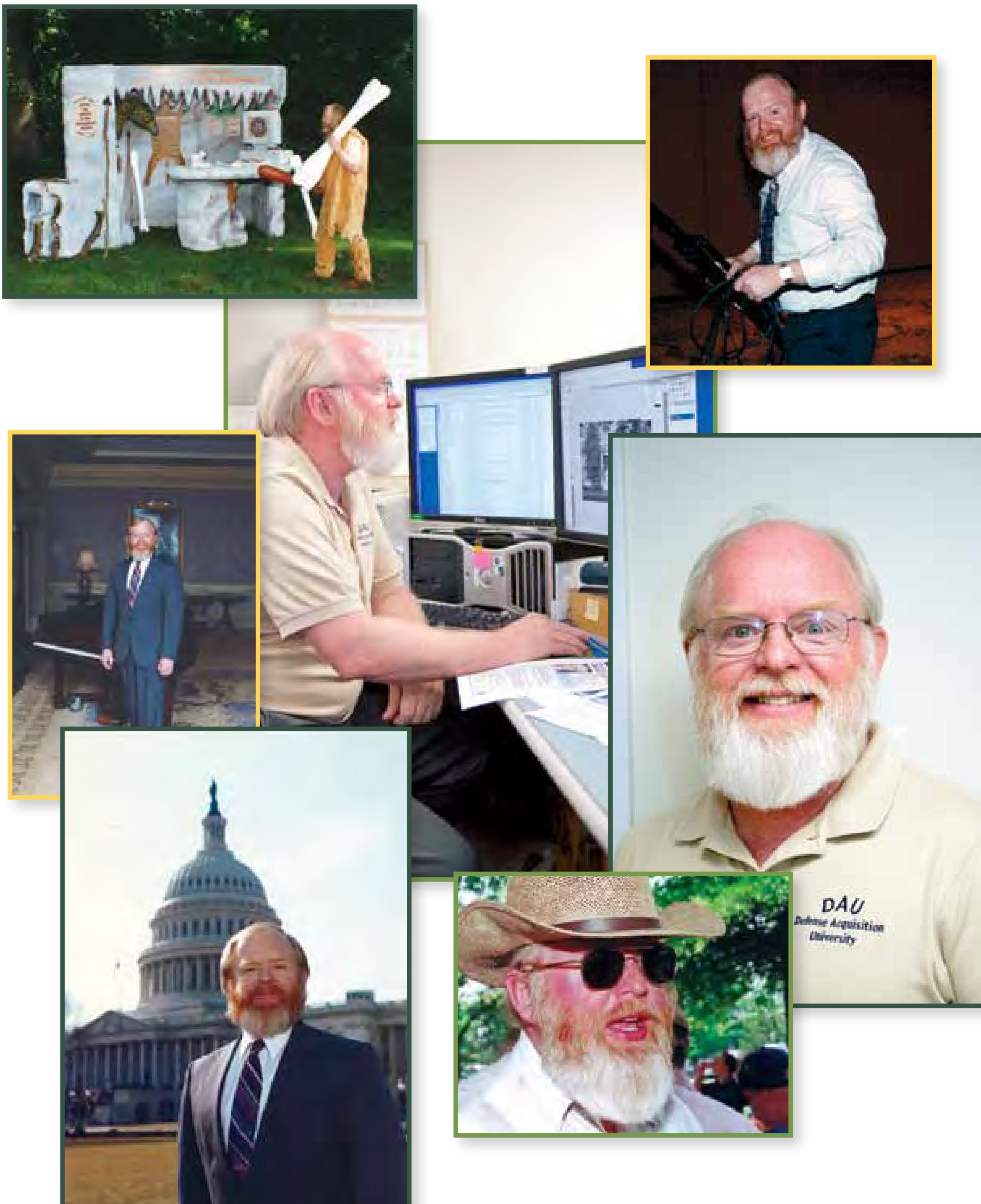
In this issue, we thank the men and women from across our defense acquisition community, who have taken their time and effort to review and critique the articles that have graced our pages in the past year. Their dedication helps us ensure that our readers are provided with the highest caliber research and analysis that can help inform their acquisition decision making.

We also take this opportunity to thank Ed Boyd, the Director of DAU Visual Arts and Press, who is retiring from public service at the end of this year. Since 2003, he has been the steady hand at the helm of DAU's publications program, helping us publicize and promote defense acquisition from the Defense Acquisition Workforce all the way to the warfighter.

Dr. Larrie D. Ferreiro
Executive Editor
Defense ARJ

FAREWELL

Eduard Boyd is the Director of Visual Arts and Press at the Defense Acquisition University (DAU). He has been with the university intermittently since 1977 and steadily since 1994. Mr. Boyd served in the U.S. Army for 22 years, the majority of which he spent gaining experience as an illustrator. He has contributed illustration support to both the Defense AT&L magazine and the Defense Acquisition Research Journal since its inception in 1994. Mr. Boyd originally came to DAU as an illustrator while he was still in the military. Upon retirement from the U.S. Army, he joined DAU as a visual information specialist in the federal civilian service. Mr. Boyd was on the cusp of the generation actively involved in transitioning illustration from a manual art to advanced computer multimedia, distributed in a myriad of delivery platforms. He embraced this evolving culture and became an expert on several software platforms, i.e., Illustrator, InDesign, which enhanced the publications program immeasurably and created a coherent branding for the university. His expertise in planning and co-designing DAU's convention and seminar exhibits during the past 20 years won him praise and accolades from the highest levels of the Department of Defense, including the Under Secretary of Defense for Acquisition, Technology and Logistics. Because of his in-depth knowledge of the organization and proven managerial skills, Mr. Boyd was promoted in 2005 to Director of Visual Arts and Press at DAU. He is the recipient of several awards during his career with the university, including numerous outstanding and superior performance awards, on-the-spot cash awards, and the Commander's Award for Civilian Service. Mr. Boyd is also a two-time recipient of the Enlisted Person of The Year award, as well as a four-time recipient of the Enlisted Person of the Quarter award.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DEFENSE
JOURNAL
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DOING MORE WITHOUT MORE

Government and Industry Imperatives for Achieving Acquisition Efficiencies

CALL FOR PAPERS

Prospective authors are invited to submit papers on the following topics:

- Affordability and Control of Cost
- Improving the Acquisition of Services
- Competition in Defense Acquisition
- Productivity and Innovation in Defense-Related Industries
- Acquisition Process

GROUND RULES

- The competition is open to anyone interested in the DoD acquisition system and is not limited to government or contractor personnel.
- Employees of the federal government (including military personnel) are encouraged to compete and are eligible for cash awards unless the paper was researched or written as part of the employee's official duties or was done on government time. If the research effort is performed as part of official duties or on government time, the employee is eligible for a non-cash prize, i.e., certificate and donation of cash prize to a Combined Federal Campaign-registered charity of winner's choice.
- First prize is $1,000. Second prize is $500.
- The format of the paper must be in accordance with guidelines for articles submitted for the *Defense Acquisition Research Journal.*
- Research papers are due November 1, 2011.
- Papers are to be submitted to the DAU Director of Research: research@dau.mil.
- Papers will be evaluated by a panel selected by the DAUAA Board of Directors and the DAU Director of Research.
- Winners will be announced and papers will be presented at the DAU Acquisition Community Symposium in April 2012.

DEFENSE ***ACQUISITION RESEARCH*** JOURNAL

ISSUE **60** OCTOBER 2011 VOL. 18 NO. 4

DIAGNOSING KEY DRIVERS OF JOB IMPACT AND BUSINESS RESULTS ATTRIBUTABLE TO TRAINING AT THE DEFENSE ACQUISITION UNIVERSITY

Nick Bontis, Chris Hardy, and John R. Mattox

The Defense Acquisition University (DAU) is an integral component in the career of every Defense Acquisition Workforce member, from the time they enroll in their first DAU course until they retire. One of the many keys to DAU's success is its ability to measure the effectiveness of its training programs, monitor performance, and improve its curriculum. To this end, the authors conducted a data mining exercise within the training evaluation data to determine the key drivers of its success. This article explains the methodological approach used (structural equation modeling) as well as the results, recommended actions, and outcomes. Within the DAU learning enterprise, more than 326,000 training events were evaluated during 19 months between January 1, 2008, and July 30, 2009. Results indicate that DAU's learning enterprise positively influences job impact and business results.

Keywords: *Structural Equation Modeling, Learning Effectiveness, Job Results, Courseware Quality, Worthwhile Investment*

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CHALLENGES IN MANAGING LARGE PROJECTS
J. RONALD FOX AND DONN B. MILLER
GLOSSARY OF DEFENSE ACQUISITION ACRONYMS & TERMS
11 TH EDITION SEPTEMBER 2003
DAU Press

The Defense Acquisition University (DAU) is critical to ensuring the Defense Acquisition Workforce is well trained to meet our nation's needs. As such, DAU is fully integrated in the careers of its workforce from the time they enroll in their first DAU course until they retire. One of the many keys to DAU's success is its ability to measure the effectiveness of its training programs, monitor performance, and improve its curriculum (DAU, 2010). To this end, DAU conducted a data mining exercise with its training evaluation data to determine the key drivers of its success.

DAU measures and monitors its own performance by administering a state-of-the-art, end-of course survey instrument, which is a Web-based learning evaluation system with an extensive database of performance benchmarks collected from student survey data. DAU evaluates customer satisfaction based on the 4-level Kirkpatrick training assessment model and uses survey items on a 7-point Likert-type scale (Kirkpatrick, 1998). Students are provided a link to the survey at the end of each course, which includes questions on course content, quality of faculty, and job applicability. Ratings are reviewed regularly, and improvements are made in DAU's learning products and services based on these evaluations.

This study focuses on the evaluation of key drivers for successful training events. An advanced statistical approach called causal modeling (i.e., structural equation modeling) was used to determine relationships among latent constructs and isolate likely paths of causation. The main objectives of this research study were fourfold.

1. Evaluate the survey instrument DAU uses and determine whether or not it is a valuable instrument to provide information for decision making;
2. Assess the relationship between job performance and impact as perceived by participants attributed to DAU training;
3. Access the antecedents and outcomes of learning and provide a benchmarking analysis of DAU scores versus other organizations; and
4. Provide recommendations for isolated points of intervention, which will yield the largest improvements for the learning enterprise.

Development of Hypotheses

Although the investment in learning by various organizations is far from consistent across industries (or even across departments within the same organization), few would argue as to its importance. The resultant training and development budget isolates this investment and is often referred to when senior leaders are questioned

as to their commitment for human capital development. The two primary expenditures related to training are instruction and materials. High levels of instructor quality are synonymous with effective learning. This positivist relationship is at the foundation of why instructors are continually evaluated. The performance of a teacher as expressed by a student after a course is complete is a universally adopted founding tradition of every educational institution. For this reason, a common expectation is the existence of a positive relationship between instructor effectiveness and individual learning.

Hypothesis No. 1

There is a positive relationship between instructor effectiveness and individual learning. In addition to the quality of instruction, courseware quality is also an important antecedent to learning. Whether the materials are physical in the form of books and notes, or online, students grasp difficult concepts by reading them over and over again. While the instructor may reinforce the importance of the text, the explicit documents act as a permanent record of the content that a student is expected to master. As such, four additional important hypotheses regarding business results and impact were also tested.

Hypothesis No. 2

There is a positive relationship between courseware quality and individual learning. Given the assumption that an instructor is competent and that course materials are adequate, students often have pre-conceived notions with regards to the value of a course before it has been completed. To be accurate, the perception of a worthwhile investment is more than just the cost of the registration fee. In most cases, the opportunity cost of time while sitting through a course (and therefore, not doing the job) is often more valuable to the learner. Only when both these perceptions (i.e., the cost of registration and the opportunity cost of time) are deemed to be fair and adequate, can a student realize a satisfactory learning experience. Therefore, the perception of a worthwhile investment is also expected to have a positive relationship with individual learning.

Hypothesis No. 3

There is a positive relationship between worthwhile investment and individual learning. Sustainable high levels of organizational performance can be attributable in large part to a superior learning enterprise that transforms human capital development into actionable job impact and business results (Bontis & Fitz-enz, 2002). It follows then that an expected positive relationship between individual learning and job impact and business results should be realized.

The issue here is one of temporal lag. How do learners know for sure if a course will impact their job later? One way to deal with this limitation is to assess the outcomes longitudinally. In other words, provide learners with an opportunity to predict an outcome immediately after the course is complete, and then again sometime into the future, a retrospective analysis. As such, the following important hypotheses regarding business results and impact were also tested:

Hypothesis No. 4

There is a positive relationship between individual learning and future job impact.

Hypothesis No. 5

There is a positive relationship between individual learning and future business results.

Hypothesis No. 6

There is a positive relationship between individual learning and actual job impact.

Hypothesis No. 7

There is a positive relationship between individual learning and actual business results.

Method

When analyzing large sets of data, a variety of statistical techniques are available. One common approach used by researchers is null hypothesis testing with experimental and quasi-experimental designs (Shadish, Cook, & Campbell, 2002). An alternative approach is data modeling (Rodgers, 2010). Structural equation modeling (SEM) is one such approach and is useful for many reasons. Foremost is its ability to test multiple hypotheses simultaneously and produce a visual model of the causal relationships within a data set. While the benefits of SEM are plentiful, a significant level of interpretation of these models is necessary. In its simplest form, SEM is an advanced statistical technique that computes the mathematical relationships among multiple variables simultaneously in order to describe a chain of causation.

The measurement and structural models were estimated by using Partial Least Squares (PLS). PLS is a second generation SEM technique that has received positive recognition in the scientific community (Chin, 1998; Gefen, Straub, & Boudreau, 2000). PLS was developed by Wold (1975), and it focuses on maximizing the

variance of the dependent variables explained by the independent ones. It is a rigorous SEM technique that requires only minimal assumptions about the distribution of the data. PLS has five main advantages over other covariance methods (e.g., LISREL,[1] AMOS,[2] etc.) for this research study: (a) it does not assume normally distributed raw data; (b) the presence of multicollinearity in the data is handled well; (c) it is better suited to explain complex exploratory relationships; (d) it allows variable weights to scale for indicators; and (e) it allows the use of noninterval scales. The raw data set that was to be analyzed fit well with the corresponding advantages of PLS. Furthermore, PLS is often used in exploratory research with the ultimate goal to maximize the explanatory power of the resultant model. PLS also benefits from considering all path coefficients simultaneously, allowing analysis of direct, indirect, and spurious relationships and the estimation of multiple individual item loadings in the context of a theoretically specified model rather than in isolation (enabling researchers to avoid biased and inconsistent parameter estimates for equations).

Results

Whereas in traditional path analysis the calculation of reliability and validity statistics is independent of the model being tested, PLS generates a variety of reliability and validity statistics calculated in the context of the theoretical model under investigation. To validate the measurement model, the authors executed the following series of steps. First, construct reliability was assured by calculating Cronbach's alpha values for each construct. Cronbach's alpha is often used to confirm that respondents interpreted the meaning of survey items accurately, and would continue to do so in the future. In other words, survey items were understood by the respondents and tended to hang together in a cluster. A Cronbach's alpha value exceeding 0.70 is considered the minimum threshold (Cronbach, 1951). Table 1a outlines that all items and their corresponding constructs used in this study exceeded 0.70 (in fact, most exceeded 0.90).

Loading values (lamdas) were used to measure the validity of items. This test examines whether or not the survey items used to evaluate the effectiveness of the instructor (four items in this case) load on to an overall construct about the instructor. The opposite would be if a survey item used to measure the quality of instructors actually did a better job of measuring courseware quality. Again, a measure of 0.70 or higher is desired, and this minimum threshold was exceeded in all cases (Nunnally, 1978). The results of Table 1b

TABLE 1A. MEASURES OF RELIABILITY AND VALIDITY FOR EXOGENOUS CONSTRUCTS

ID	Metric (Base, DAU)	Lamda	
Instructor Effectiveness (Alpha = 0.946, 0.931)		**Base**	**DAU**
1058P	The instructor was knowledgeable about the subject.	0.895	0.910
1059P	The instructor was prepared and organized for the class.	0.885	0.923
1269P	The instructor was responsive to participants' needs and questions.	0.856	0.913
1270P	The instructor's energy and enthusiasm kept the participants actively engaged.	0.851	0.906
Courseware Quality (Alpha = 0.899, 0.798)			
1065P	The examples presented helped me understand the content.	0.886	0.805
2726P	The scope of the material was appropriate to my needs.	0.891	0.806
2730P	The participant materials (manual, handouts, etc.) will be useful on the job.	0.845	0.800
2924P	The material was organized logically.	0.892	0.779
Worthwhile Investment (Alpha = 0.958, 0.971)			
2743P	This training was a worthwhile investment in my career development.	0.980	0.986
2744P	This training was a worthwhile investment for my employer.	0.979	0.986
Individual Learning (Alpha = 1.000, 1.000)			
919P	I learned new knowledge and skills from this training.	1.000	1.000

illustrate that both the survey instrument and DAU models used valid and reliable measurement instruments. In essence, the psychometric evaluation of the scales used in this study was successful and therefore adequate for model interpretation.

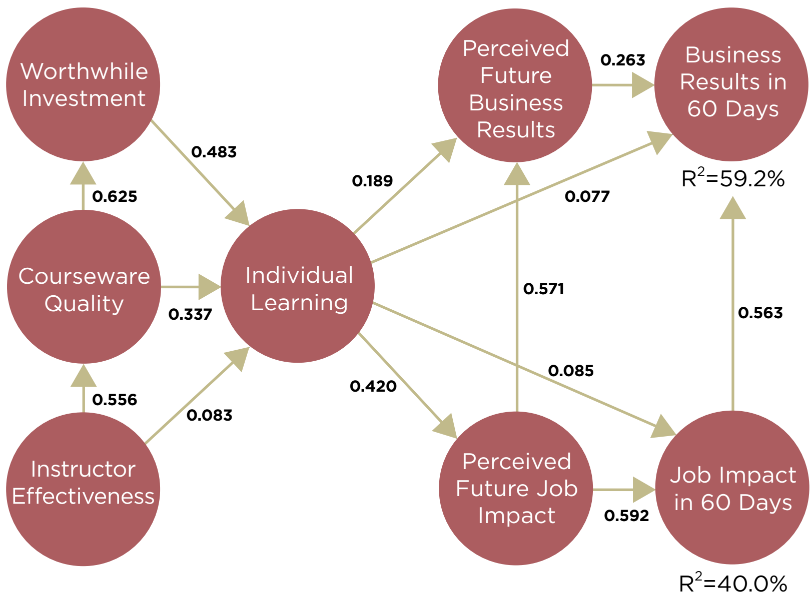
Survey Instrument vs. DAU Model Interpretation

In 2009, Dr. Nick Bontis created a predictive learning analytics model that describes the relationship between training and business performance (Bontis & KnowledgeAdvisors, 2009). The analysis proved successful and the resulting model is depicted in Figure 1. As one might expect, the model is complex. However, the model is relatively easy to decipher with one key piece of information. The chain of causation lies along the pathways with the highest beta values.

TABLE 1B. MEASURES OF RELIABILITY AND VALIDITY FOR ENDOGENOUS CONSTRUCTS

ID	Metric	Lamda	
Perceived Future Job Impact (Alpha = 0.832, 0.833)		**Base**	**DAU**
712P	I will be able to apply the knowledge and skills learned in this class to my job.	0.726	0.749
1279P	How critical is applying the content of this training to your job success? 0%–100%	0.786	0.925
1423P	What percent of your total work time requires the knowledge or skills presented in this training? 0%–100%	0.840	0.898
2788P	What percent of new knowledge and skills learned from this training do you estimate you will directly apply to your job? 0%–100%	0.873	0.907
Perceived Future Business Results (Alpha = 0.775, 0.805)			
2740P	Estimate how much you expect your job performance related to the course subject matter to improve in the next 12 months. 0%–100%	0.909	0.928
2741P	Based on your response to the prior question, how much of the improvement will be a direct result of this training, as opposed to other factors? 0%–100%	0.898	0.901
Job Impact in 60 days (Alpha = 0.892, 0.929)			
1737F	What percent of your total work time have you spent on tasks that require the knowledge/ skills presented in the training? Check only one. 0%–100%	0.889	0.932
1738F	On a scale of 0% (not at all) to 100% (extremely critical), how critical was applying the content of the training to your job success? Check only one.	0.916	0.934
2818F	What percent of new knowledge and skills learned from this training did you directly apply to your job? Check only one. 0%–100%	0.912	0.942
Business Results in 60 days (Alpha = 0.708, 0.814)			
2751F	Given all factors, including this training, estimate how much your job performance related to the course subject matter has improved since the training. 0%–100%	0.906	0.931
2502F	Based on your response to the prior question, estimate how much of the improvement was a direct result of this training. 0%–100%	0.845	0.905

FIGURE 1. PREDICTIVE LEARNING ANALYTICS MODEL



Note. Adapted from *The Predictive Learning Impact Model* by N. Bontis and *KnowledgeAdvisors, Inc. Copyright 2009 by KnowledgeAdvisors, Inc.*

Before examining the model, a description of the data source is essential. Data used in the analysis were extracted from the survey instrument system. Using Web-hosted surveys, learners provided feedback about their training experience immediately after training and 60 days after training. The immediate survey asked learners to rate the quality of their training experience as well as predict whether training would improve their job performance and, in turn, contribute to business results. In the model shown in Figure 1, the immediate survey results contribute to the following factors about training: *Instructor Effectiveness*, *Courseware Quality*, *Worthwhile Investment*, and *Individual Learning*.

The immediate responses also contributed estimates of future job performance and estimated impacts on business results: *Perceived Future Job Impact* and *Perceived Future Business Results*. The far right side of the model has two factors, *Job Impact in 60 Days* and *Business Results in 60 Days*, which represent retrospective input gathered from learners after they have had 60 days to apply their learning on the job. More than a million data points were used in the survey instrument base model with learners assessed from many well-known, globally recognized companies (e.g., Microsoft, HSBC, Caterpillar, and BAE).

The left side of the model represents the three most important antecedent aspects of training: *Worthwhile Investment*, *Courseware Quality*, and the learner's perspective about *Instructor Effectiveness*. But how do these three factors contribute to individual learning? Effective instructors contribute by developing high-quality courseware (ß = 0.556) (e.g., materials, delivery format, learning environment, etc.). Both contribute to the learner's perception that training was a worthwhile investment (ß = 0.625). While each factor also has a direct relationship with individual learning, the strongest relationship is through the last factor—worthwhile investment (ß = 0.483).

The second half (right side) of the model represents how individual learning influences job performance and business (organizational) outcomes. By examining the values, we see from the nondominant (lowest values) paths that individual learning does *not* have a strong direct effect on *Job Impact* and *Business Results* directly (both far right) 60 days after training. However, by following the dominant paths, we see that *Individual Learning* leads to *Perceived Future Job Impact*, actual *Job Impact in 60 Days* and *Business Results in 60 Days*. This path indicates that knowledge for the sake of knowledge (Newman, 1947) is not sufficient. Training must be perceived as relevant, practical, and applicable before learners will indicate it will (and does) have an impact on performance and eventually business results. The entire causal pathway for the model looks like a giant N, starting at the bottom left, rising to the top left, slanting diagonally to the bottom right, and then up to the top right.

Does the model effectively describe the relationship among variables? Yes, the model has a relatively high explanatory power for predicting *Job Impact in 60 days* (R^2 = 40.0%) and *Business Results in 60 days* (R^2 = 59.2%). A model that predicts the structure and relationships perfectly would have an R^2 value of 100 percent, although this situation is virtually impossible to achieve in social science research. To put this measure in perspective, consider that it is an algorithm you could use at a casino. Given the value of the cards in your hand (e.g., *Instructor Effectiveness*, *Courseware Quality*, etc.), you would win 59.2 percent of the time.

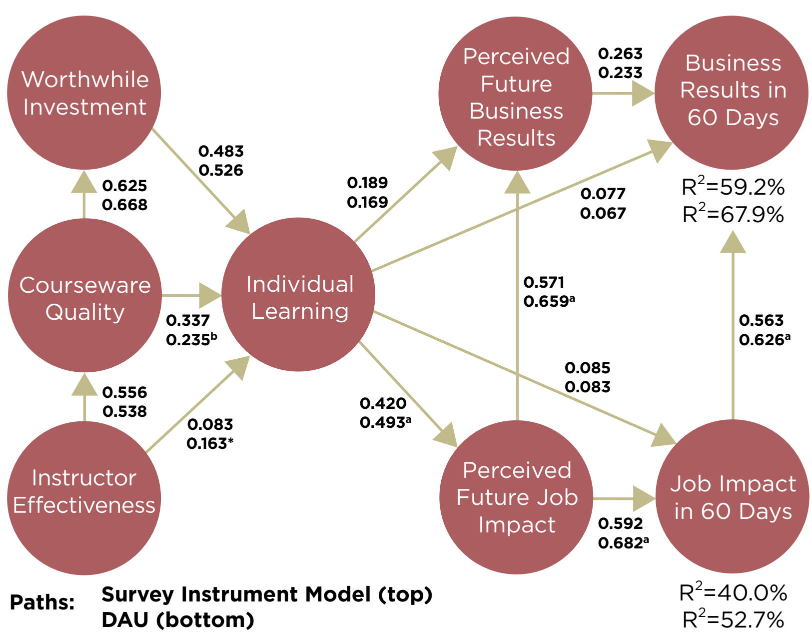
This predictive learning analytics model (KnowledgeAdvisors, Inc.) is relevant to DAU because it serves as a base model (derived from a data set of over 1 million surveys industry-wide) for benchmarking purposes. As a result, the DAU can compare its model and results to the KnowledgeAdvisors' predictive learning analytics model to determine where it can improve and where it is outperforming other organizations.

The DAU Model

Each year the DAU collects hundreds of thousands of evaluations after training events to determine whether the curriculum and its outcomes were effective. Immediate postcourse evaluations are deployed as well as 60-day follow up evaluations. In this way, learners provide feedback about the quality of the course and predict whether they will apply what they learned. On the 60-day follow up evaluation, learners indicate whether training contributed to improved job performance and business results. For this study more than 326,000 evaluations were collected during 19 months between January 1, 2008, and July 30, 2009.

Figure 2 shows the DAU model with KnowledgeAdvisors benchmark values above the DAU model values. The analysis reveals many important facts about the DAU's curriculum.

FIGURE 2. PREDICTIVE LEARNING ANALYTICS MODEL—DAU AND SURVEY INSTRUMENT MODEL BENCHMARK



First, the causal chain depicted in the model explains the relationships among the data well. In fact, the model fits the DAU's data better than the survey instrument benchmark data. (This is not unusual; the model will fit some data sets better or worse than the benchmark.) The model predicts 52.7 percent of the *Job Impact in 60 Days* and 67.9 percent of the *Business Results in 60 Days*. The values for the KnowledgeAdvisors Benchmark data are lower at 40.0 percent and 59.2 percent, respectively. These results indicate

that the key aspects of training that drive job impact and business performance hold true for both the KnowledgeAdvisors Benchmark data and the DAU data. As a refresher, *Instructor Effectiveness* links to *Courseware Quality*, which links to *Worthwhile Investment*. All three in that order optimize *Individual Learning*. In turn *Individual Learning* leads to *Perceived Future Job Impact*, *Job Impact in 60 Days*, and then *Business Results in 60 Days* in that order. To improve the effectiveness of courses—at least in terms of increasing job performance and business impact—DAU should focus on *Instructor Effectiveness*, *Courseware Quality*, and ensure that learners perceive that training is a *Worthwhile Investment*. Improvement actions will be discussed later in this article.

Second, the strength of the causal relationships is somewhat stronger for the DAU compared to the KnowledgeAdvisors Benchmark for five relationships (arrows). These are designated with a superscripted [a] after the value. For only one relationship, the link between *Courseware Quality* and *Individual Learning*, the DAU value is lower than the survey instrument benchmark and is indicated by a superscripted [b]. When this relationship was examined in more detail, it was discovered that *Courseware Quality* was more important for younger learners and less so for older learners. Younger learners preferred e-learning, whereas older learners preferred traditional classrooms and effective instructors. Interestingly, younger learners indicated that training had a greater impact on job impact and business impact 60 days after training.

Third, DAU instructors have a strong influence on *Individual Learning* and eventually *Job Impact* and *Business Results*. In fact, when compared to the KnowledgeAdvisors benchmark (0.083), the relationship between *Instructor Effectiveness* and *Individual Learning* ($ß = 0.163$) is almost twice as large for DAU. A stronger relationship between *Instructor Effectiveness* and *Courseware Quality* still exists, but by comparing the magnitude of the relationship between the DAU and the benchmark, clearly, instructors hold more influence within DAU than at other organizations.

Fourth, guest speakers also impact learning. When guest speakers taught courses, higher levels of *Individual Learning* occurred. When guest speakers were not included, *Job Impact* and *Business Results* were generally lower than the survey instrument benchmark.

Fifth, application is a critical element to successful courses. High job application scores were linked to high learning scores, extremely high *Job Impact* scores, and *Business Results* scores.

Sixth, application is also strongly linked to whether learners recommend courses for future learners. When recommendation scores were low, the *Business Results in 60 Days* were also lower. This is

a strong indicator that the course is not meeting individual needs and organizational needs and therefore should be revised or retired.

Seventh, Defense Acquisition Workforce Improvement Act (DAWIA) levels were investigated to test for their influence on training outcomes. DAWIA specifies three skill levels (Basic, Intermediate, and Advanced) associated with 13 career fields in the acquisition system. No consistent pattern of influence emerged across the model for the three DAWIA levels.

Eighth, the educational level of learners (e.g., high school, college, or graduate school) does influence outcomes of the model. Learners with some graduate education are more critical of instructors and appreciate good courseware. Learners with a high school education have the lowest perception that training is a *Worthwhile Investment*, but yield the highest response to *Individual Learning*. Interestingly, this group scored much lower than the benchmark regarding future results.

Lastly, the DAU's course offerings and their influence on job performance and outcomes were evaluated for longitudinal improvement. Indeed, it was confirmed that scores improved from 2008 to 2009. In fact, scores for every category improved except for *Instructor Effectiveness*, which was already high.

Recommended Actions

An important and useful finding of this study indicates that the key aspects of training drive *Job Impact* and *Business Results*. This in itself is valuable, but such value quickly fades if insights cannot be turned into action to improve the curriculum. Table 2 provides a summary of the results of this study as well as recommended actions. If the DAU pursues these actions, the curriculum is likely to improve as evidenced by improved scores on the training evaluations.

Conclusions

In its evolution, DAU has broadly embraced adult learning designs in its formal courses and accepted the fact that adults learn best "by doing," whether in the formal learning environment or on the job. With formal training, DAU attempts to "train as the workforce should work," and prepares the workforce to "work as they are trained" by using the same training tools and learning assets at their individual places of work that they formerly used in the classroom. This study provides strong evidence that the key aspects of

TABLE 2. RECOMMENDED ACTIONS

Results	Recommended Action
Application is a critical element of training	As appropriate, DAU can improve its impact on job performance and business results by increasing the opportunities to apply what is learned during training.
Courseware Quality is more important for younger learners	To improve learning among younger learners, invest in self-study modules and quality courseware.
DAU instructors have a strong influence on older learners	For instructor-led courses, especially with older learners as the target audience, invest time and effort to find high-quality instructors who can effectively teach the materials regardless of the quality of the courseware.
Guest speakers also impact learning	When appropriate, use guest speakers to augment or lead instructor-led courses for older learners. Guest speakers tend to have more impact on learning than the standard cadre of instructors.
Learners recommend effective training	Use the question, "I would recommend this training to other learners" as a leading indicator of the quality of training and whether it will lead to job performance and business impact. If the rating for this question is low for a given course, it should be revised with a focus on improving the ability to apply what is learned during training.
DAWIA levels do not influence training impacts	When building DAU courses, it is not necessary to consider the DAWIA level of the audience. Other factors like age and education are more influential than DAWIA levels.
Education impacts learning and performance	To ensure that training leads to performance and future results, courses should be tailored to the educational level of the audience.

DAU's approach to training drive *Job Impact* and *Business Results*. Having empirical evidence derived from relatively large data sets is very useful in rationalizing the cost of training regarding improving performance on the job. Additionally, confirming the reliability and validity of the survey instrument is important to any DAU curricula and recourse decisions based on survey instrument scores as well as other considerations.

Given that *Job Impact* results were based on self-reporting perceptions and not an independent external measure (not within the instrument), the outcome is still very strong in its implications, largely due to the size of the sample as well as previous relationship studies concerning the close relationships between measured perception and actual reality. Dess and Robinson (1984) indicate that such perceived measures of business results are reasonable surrogates for more tangible and objective measures of business outcomes (e.g., revenue growth, profits). Others (Geringer & Hébert, 1989; Hansen & Wernerfelt, 1989; Lyles & Salk, 1997; Venkatraman & Ramanujam, 1987) have demonstrated that such perceived measures also are positively correlated with objective financial performance metrics.

Finally, the recommendations discussed previously are now being incorporated within DAU course development and course update design strategies. Therein lies the power of: (a) benchmarking learning data across a very large set of comparative peer organizations; and (b) using structural equation modeling to ascertain specific points of intervention for evaluating and improving the learning enterprise, thereby assuring a healthy return on investment for training dollars.

Author Biographies

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ENDNOTES

1. **LISREL**, an acronym for linear structural relations, is a statistical software package used in structural equation modeling. LISREL was developed in the 1970s by Karl Jöreskog, then a scientist at Educational Testing Service in Princeton, NJ, and Dag Sörbom, later both professors of Uppsala University, Sweden.
2. **AMOS**, an acronym for analysis of moment structures, is designed primarily for structural equation modeling, path analysis, and covariance structure modeling, though it may be used to perform linear regression analysis. It features an intuitive graphical interface that allows the analyst to specify models by drawing them. It also has a built-in bootstrapping routine and superior handling of missing data. It reads data from a number of sources, including MS Excel® spreadsheets.


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DAU
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Thesaurus
CHALLENGES IN MANAGING LARGE PROJECTS
J. RONALD FOX AND DONN B. MILLER
GLOSSARY OF DEFENSE ACQUISITION ACRONYMS & TERMS

MOTIVATING THE KNOWLEDGE WORKER

David E. Frick

Commonly accepted economic theory suggests that workers are rational actors and make decisions that will maximize expected outcomes. As such, managers should be able to influence behaviors to meet business goals by manipulating the expectations of outcomes. Conversely, social science practitioners suggest that workers often make decisions that are irrational. Knowledge workers are a growing sector of the workforce and are the backbone for entire federal agencies. The acquisition community falls within this category. Identifying factors that influence the performance of knowledge workers may be critical to maintaining high levels of organizational performance. This research focused on identifying the factors that encourage knowledge workers to maintain high levels of performance.

Keywords: *Motivation, Knowledge Worker, Performance, Human Capital, Merit Systems Protection Board*

image designed by Tia Gray »

Positive & Negative MOTIVATING FACTORS

> "There is one right way to manage people—or at least there should be."
>
> –Peter F. Drucker

Conventional wisdom and commonly accepted economic theory suggest that workers are rational actors and make decisions that will maximize expected outcomes—maximize expected benefits or minimize expected harm. As such, managers should be able to influence behaviors to meet business goals by manipulating the expectations of outcomes. Etzioni (1971) argues that workers find this manipulation of behavior via incentives *alienating* and *dehumanizing*. Conversely, social science practitioners suggest that workers often make decisions that are irrational (from an economic perspective) and are based on cognitive biases (Santaniello, 2008). These beliefs have been formed over the last 100 years in an environment that has been dominated by agricultural, manufacturing, and industrial workers.

Knowledge workers are a growing sector of the workforce (Haag, Cummings, & Phillips, 2008). They are individuals valued for their ability to gather, analyze, interpret, and synthesize information within specific subject areas to advance the overall understanding of those areas and allow organizations to make better decisions. The knowledge worker is the backbone of many professions. Within the federal government, entire agencies are comprised mainly of knowledge workers. The members of the acquisition community principally fall within this definition.

Creating environments to encourage high performance among knowledge workers is an area long neglected by researchers. To date, no published research exists on knowledge workers in the federal government. Even the term knowledge worker was not defined until 1999 (Drucker, 1999). As a consequence of this lack of evidence, the executive branch has been forced into making strategic human capital decisions based upon theory and experiences that may not apply to the knowledge worker.

Collins (2001) looked at high-performing companies to see if he could find patterns within the cultures of the respective workforces. His methodology was questionable and his conclusions were not particularly useful, but he did make two statements that are quite provocative: "…expending energy trying to motivate people is largely a waste of time" (p. 74) and "You cannot manufacture passion or 'motivate' people to feel passionate. You can only *discover* what ignites your passion and the passion of those around you" (p. 109).

Public Service Motivation Theory (Crewson, 1997; Houston, 2000; Perry, 1996; Porter & Perry, 1982; Perry & Wise, 1990) suggests that individuals who self-select into government service are

motivated by a set of factors (self-sacrifice, desire to serve the public, desire to serve a higher power) that is more intrinsically centered than the set of factors that motivates private sector workers. Small contingency-based rewards, such as the insubstantial pay increases common in government pay-for-performance systems, tend to crowd out these intrinsic factors.

Public administration literature also makes a distinction between employee motives and work motivation. Motives are the rewards that workers would like to receive for their jobs, while work motivation is defined as the drive workers have to perform their jobs well within the rewards offered by the government and private sectors. Workers self-select into either the public or private sector based on whether the incentive structure is aligned with their individual values and motives (Rainey, 1982).

A significant weakness in the civil service is the inability, in practice, of managers to weed out inferior performers. In 2008, the federal government only fired 11,165 employees (0.57 percent of the workforce) (Losey, 2009). Compare this with the Merit Systems Protection Board (MSPB) estimate that 3.7 percent of the federal workforce are poor performers (Office of Personnel Management [OPM], 1999, p. 1). For business, especially those in "employment at will" states, the process of eliminating substandard performers is significantly less arduous than in the civil service. The danger of frivolous claims of discrimination always remains, but on balance, business has a flexibility that the government does not have...in practice. Yes, the civil service rules do allow for removing nonperformers, but the process is labor-intensive for supervisors, extremely drawn out, and subject to a number of administrative reviews that tend to encourage supervisors to use an alternate method for eliminating inferior performers—in other words, "passing the trash" (Shuger, 1999).

Workforce mobility in the civil service is rooted in the "Peter Principle"—primarily centered on upward mobility. The way to get promoted is to find a job vacancy at a higher grade and compete against other applicants. In most hiring processes, performance evaluations are a consideration in the hiring decision. Some low-performing supervisors have been known to artificially inflate the performance evaluations of inferior supporters with the goal of passing the trash to someone else (Shuger, 1999; Peter & Hull, 1969). Yes, this is unfortunate and not in the best interest of the public good, but it happens at all levels.

Additionally, the civil service exhibits a characteristic that many workers find invaluable, especially Baby Boomers and, to a lesser extent, "Gen X'ers"—job security (Alsop, 2008). Job security has a value (Crewson, 1997; Houston, 2000). It is reasonable to concede

to the employer, the taxpayer in the case of civil service, something of equal benefit for the benefit of job security. Historically, that has been a pay structure that has, arguably, lagged behind the free market. Job security is the tradeoff for a lagging pay policy. Pay for performance appears to be a technique to solve the "lagging pay" issue that does not have an equitable tradeoff for the employer (the people of the United States).

Purpose of the Study

The author designed a study to gather the opinions of a group of independently identified, high-performing federal civilian employees from multiple agencies to develop a rank-ordered list of factors that may be most effective in establishing an environment that motivates high-performing knowledge workers to maintain high levels of performance. All participants in this survey appear to meet the definition of knowledge worker.

Theoretical Framework

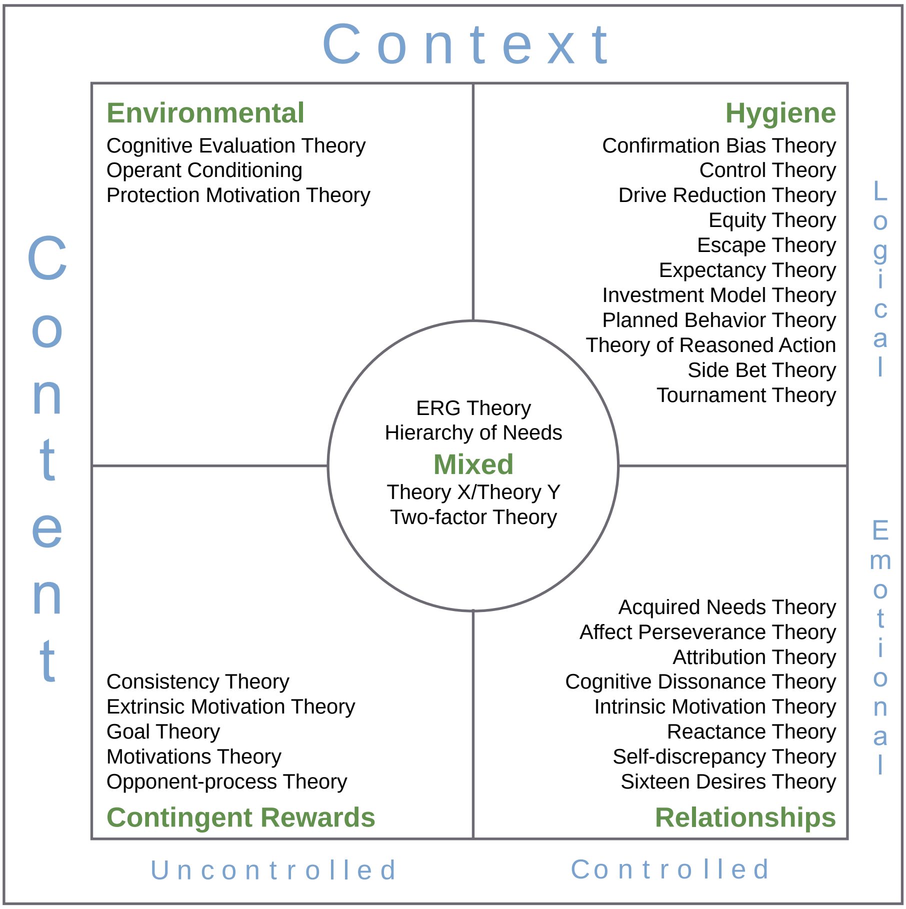
No universally accepted model of motivation is inherent to a business environment. To facilitate a structured approach to the analysis of the various theories of motivation and the data collected from this effort, the author developed a two-dimensional model of the factors that motivate workers (Table 1).

TABLE 1. FRAMEWORK AXES

Factor	Description
Logical	Associated with a process either inductive or deductive. Elements tend to be more tangible than intangible. Cognitive.
Emotional	Associated with responses that are based upon intuition, prior learning, perceptions, and desires.
Controlled	Elements, decisions, or expectations can be formed by the individual. The world tends to be defined by internal filters.
Uncontrolled	Elements, influences, conditions, and constraints are established by either the environment or an outside actor. The world tends to be defined by external filters.

The *horizontal axis* represents the universe from a contextual viewpoint. The *vertical axis* takes the content viewpoint. Context, from the viewpoint of the worker, can be either controllable or uncontrollable. Content is either logical (tangible-cognitive) or emotional (intangible-instinctual). The four quadrants represent environmental and hygiene factors, contingent rewards, and relationships. The central area is reserved for those theories or factors that have mixed characteristics or do not clearly fit into a quadrant (Figure).

FIGURE. THEORETICAL FRAMEWORK



Significance of the Study

As the U.S. economy and those government agencies that support the nation's institutions become more dependent upon knowledge workers, the need to fully understand those conditions

that encourage continued high performance among knowledge workers becomes more important.

This research identified a set of conditions that are effective in cultivating a state of positive motivation among knowledge workers of the federal workforce. Identifying those factors that this one specific subset of the workforce believes are most motivating may provide strategic leaders with the empirical information needed to make more effective decisions. Likewise, allowing managers to more effectively commit organizational resources will further the goal of improving overall performance of the entire workforce.

Method—Highlights

The target population was the 2009 Fellowship of the Council for Excellence in Government (CEG) of the Partnership for Public Service. This population, which represented a high-performing subset of the federal workforce, was selected for convenience. A precise definition of, and contact information for, the entire population was available to the author.

There were 132 federal workers in the population. The sample was self-selected. All subjects were volunteers. Sixty-four members of the cohort agreed to participate in the study. The sample suffered from self-selection bias.

A survey instrument was created for this study. A wide range of structured, demographic information was collected. Opinion questions were open-ended, but included a forced distribution system. A number of uncommon demographic categories were included in the hope of serendipitous findings and to ascertain whether the sample was similar to the entire federal workforce or the general population.

The author was able to infer that the subjects were high-performing by their participation in the highly competitive CEG program. The cost to the agencies to participate was $10,000 per participant. Replicating this study by assembling a similar group comprised only of high-performing workers in any other environment would prove difficult.

While this study may show clear preferences of the workforce, it was not able to show a causal relationship between identified factors and workforce performance.

Questions self-report preferences; therefore, problems of self-report bias need to be taken into account, as responses may not be completely accurate (Rosenthal & Rosnow, 1991). Additionally, appropriate group norms in this research area to interpret measures were not available.

In-depth validity and reliability studies of the survey instruments were not conducted.

The sample used in this study was relatively small and admittedly atypical of the entire federal workforce. Generalization to all federal knowledge workers or the acquisition workforce, in particular, was not possible.

Knowledge Worker

Knowledge workers are generally professionals such as teachers, lawyers, architects, physicians, nurses, engineers, and scientists. As businesses increase their dependence on information technology, the number of fields in which knowledge workers must operate has expanded dramatically.

The term was first coined by Peter Drucker in 1959, and later refined in 1999, as one who works primarily with information or one who develops and uses knowledge in the workplace (Drucker, 1973, 1999). Some tasks that are performed by the acquisition community do not fall within the definition of knowledge work; however, those aspects that involve making judgments and trade-off decisions clearly do.

Drucker (2001) added to the definition of knowledge workers by describing their fundamental tasks.

> To be sure, the fundamental task of management remains the same: to make people capable of joint performance through common goals, common values, the right structure, and the training and development they need to perform and to respond to change. But the very meaning of this task has changed, if only because the performance of management has converted the workforce from one composed largely of unskilled laborers to one of highly educated knowledge workers. (p. 4)

> Even if employed full-time by the organization, fewer and fewer people are 'subordinates'—even in fairly low-level jobs. Increasingly they are 'knowledge workers.' And knowledge workers are not subordinates; they are 'associates.' For, once beyond the apprentice stage, knowledge workers must know more about their job than their boss does—or else they are no good at all. In fact, that they know more about their job than anybody else in the organization is part of the definition of knowledge workers. (p. 78)

Literature

How do the best managers in the world build the foundation for a strong, high-performing workplace? No clear answer can be found. In 1975, 200 books were published on the topic of management and leadership. By 1997, that number had tripled (Buckingham & Coffman, p. 53). A quick search today of the website *Amazon.com* with the keywords "management and leadership" yields over 350,000 results.

With respect to people, Reiss (2000) suggests that there are 16 distinct basic desires that "make our lives meaningful." He claims that everyone displays each of these desires either strongly, moderately, or weakly. If his hypothesis is valid, then there are a possible 43,046,721 distinct possible personality types, while Myers and Briggs claim 16 distinct personality types (Myers & Myers, 1995).

A little closer to home, my own mother unhesitatingly classified workers into two distinct personality preferences. "There are two kinds of people—those who do the work and those who take the credit, " she would often say. She did not realize she was quoting Indira Gandhi, who went on to add, "Try to be in the first group; there is less competition there."

But whether there are 2, 16, or 43 million different types of people, finding a single model to portray how all people are motivated has proven to be extremely difficult.

Theories of Motivation

Business is constantly looking for *the* best practice and often engages an expert to demonstrate the *one best way*. Drucker (2001) often spoke of the futility of management practitioners in finding the one right theory or the one right way to manage, and the belief that one exists.

> *Basic assumptions about reality* are the *paradigms* of a social science such as management. They are usually held subconsciously by the scholars, the writers, the teachers, the practitioners in the field, and are incorporated into the discipline by their various formulations. Thus, those assumptions by this select group of people largely determine what the discipline assumes to be *reality*. (p. 69)

These assumptions underlie practically every book or paper on the management of people.

Regrettably, in motivating workers, *there is no best practice*; there is no *Grand Theory on Motivation*; there is no commonly accepted model of motivation.

At least 34 principal theories of motivation have some application to business. Most are contradictory. The reason is simple... people are complex animals. Business practitioners have long searched for the *one right* business model, the *one right* organizational structure, the *one right* management style, and the *one right* way to treat employees (Drucker, 2001). So far that search has been in vain.

One way to look at these theories is to classify them by motivating factors from the perspective of the worker. These factors represent the worker's preference, e.g., for a given worker, contingent rewards might be more effective in achieving desired behaviors than personal relationships. The figure represents the author's interpretation of each of these theories with respect to the framework.

An examination of all of these theories is well beyond the scope of this article. Nonetheless, the following discussion focuses on motivational theorists of some note.

Theorists in the Business Environment

The theories of Maslow, McGregor, and to a lesser extent, Herzberg, are the most commonly accepted in business literature. At lower levels of Maslow's hierarchy of needs, such as physiological needs, money is a motivator; however, it tends to have a motivating effect on employees that lasts only for a short period. At higher lev-

els of the hierarchy, praise, respect, recognition, empowerment, and a sense of belonging are far more powerful motivators than money.

McGregor (1960) asserted that management must choose between two and only two different ways of managing people—"Theory X" and "Theory Y"—and then asserted that Theory Y is the only sound one. Drucker (2001, p. 77) points out a few years later that Maslow suggested in his *Eupsychian Management* (1965), republished as *Maslow on Management* (1998), that McGregor was wrong. He showed conclusively that "different people have to be managed differently."

Herzberg differentiated hygiene factors from motivators in the *length of time* the particular factor continues to drive behaviors. Salary (base pay) has a short motivational time span. "An employee might receive a pay raise today, and 30 days later begin to question when the next raise will be forthcoming. Meanwhile, the current salary has little influence on…willingness to improve performance" (Henderson, 2002, p. 391).

Maslow has money at the lowest level of the hierarchy and shows other needs are better motivators to employees. McGregor places money in his Theory X category and considers it as a poor motivator. Praise and recognition are placed in the Theory Y category and are considered stronger motivators than money. Likewise, McClelland (1987) noted that workers could not be motivated by the mere need for money—in fact, extrinsic motivation (e.g., money) could extinguish intrinsic motivation such as achievement motivation, though money could be used as an indicator of success for various motives, e.g., keeping score.

In *The Peter Principle* (Peter & Hull, 1969), we were warned that if managers follow the path of conventional wisdom without question, they tend to promote each person to his or her level of incompetence. It was true then, and it is true now.

Buckingham and Coffman (1999) note little or no change to this conventional wisdom.

> Unfortunately, in the intervening years, we haven't succeeded in changing very much. We still think that the most creative way to reward excellence in a role is to promote the person out of it. We still tie pay, perks, and titles to a rung on the ladder: the higher the rung, the greater the pay; the better the perks, the grander the title. Every signal we send tells the employee to look inward and upward. 'Don't stay in your current role for too long,' we advise. 'It looks bad on the resume. Keep pressing, pushing, and stretching to take that next step. It's the only way to get ahead. It's the only way to get respect.' (p. 178)

Public Service Motivation

"The theory of public service motivation (PSM) suggests public employees are more likely than private sector employees to hold pro-social values and seek opportunities to help others benefit society" (Wright, 2007, p. 5). The term seems to have been coined by Perry and Wise (1990, p. 368).

"The public administration literature argues that individuals employed by the government have a unique sense of public service that leads them to value intrinsic rewards more keenly than extrinsic rewards, although few studies have investigated the concept empirically" (Santaniello, 2008, p. 1).

According to Perry (1996, p. 6), PSM is defined as "an individual's predisposition to respond to motives grounded primarily or uniquely in public institutions and organizations." Attraction to policy making, commitment to the public interest, compassion, and self-sacrifice are all identified as key components of PSM as opposed to extrinsic motivations (specifically pay) that are central to many rational choice models of motivation and provide the basis for pay-for-performance structures. This theory contradicts the conventional wisdom of economic theory (Santaniello, 2008, p. 3).

Public administration literature makes a distinction between employee motives and work motivation. Motives are the rewards that individual employees would like to receive for their jobs, while work motivation is the drive employees have to perform their jobs well within the context of their organizations (Wright, 2007).

Poor Performers in the Federal Government

The best estimate of the proportion of poor performers in the federal workforce is 3.7 percent. While no good benchmarks exist in the private or public sectors, such comparison is undoubtedly lower than conventional wisdom. Supposedly, the federal government has no serious performance problems (OPM, 1999, p. 1).

Nonetheless, the prevailing perception about public service employment is that poor performance is a big problem. Moreover, civil service employees are among the first to speak up about the situation. In questionnaire after questionnaire, civil service employees express disdain for a management team that they say cannot or will not remove from their midst coworkers who are not carrying their share of the load. In a 1997 report entitled *Adherence to the Merit Principles in the Workplace*, the MSPB reported that, among the 9,700 federal employees it surveyed, the issue of handling poor performance was the deepest area of concern. Nearly half of the respondents said that agencies had a major problem correcting

poor performance, and even more said the same thing about the firing of poor performers (OPM, 1999, p. 3).

As part of its Fiscal Year 1998 oversight program, the OPM examined the foundation for the suspicion that the government has too many poor performers. To do this, they identified a random sample of employees and interviewed their supervisors. For those employees identified as “poor performers,” the supervisors were asked what caused the employee’s poor performance, what was done to address the problem, and what had been achieved as a result. In a separate interview sample, OPM contacted supervisors who had successfully taken a formal action to deal with a poor performer, to obtain descriptions of their experiences, and to record the lessons they learned. Finally, OPM looked at the private sector and public sector for points of comparison. The implication is that these problems are less prevalent outside the federal government (OPM, 1999, p. 4).

To exacerbate this prevailing perception, surveys find that most federal workers do not believe that the best qualified people are the ones receiving promotions (MSPB, 2001, p. 7). Sometimes, the motivation to retain poor performers is rooted in the federal hiring process. The White House has noted that it can often take 18 months or longer to fire employees, thus requiring a major commitment of time and effort from managers (Edwards & DeHaven, 2002, p. 2).

Most managers try to work around bad employees or try to reassign them to other groups. OPM surveys consistently find that managers think that “procedures dealing with poor performance are too complicated, time consuming, or onerous; they do not get higher management support; and they perceive their decisions will be reversed or that they will be falsely accused of discrimination in their actions” (OPM, 1999, p. 1). Those fears are justified given that federal workers lodge discrimination complaints at 10 times the rate of nonfederal workers (OPM, 1999, pp. 3, 11).

Another problem is that poor performers often receive good performance reviews from negligent managers who do not want to rock the boat. There is an ingrained federal culture to score virtually all workers highly—the MSPB has found that just 1 percent of federal workers are rated below “fully successful” in annual reviews (MSPB, 1999, p. 12).

The various theories of motivation are too contradictory to suggest the “one right answer.” The search for the one or two best ways to manage people has been in vain. When you add human nature with its myriad cognitive biases to the mix, management action often leads to outcomes that have a net negative effect. The lack of empirical evidence to paint a clear picture of the emerging knowledge worker makes the challenges of picking the right solutions

even harder. Understandably, business and government leaders of today may make strategic decisions that, only in hindsight, prove to be ineffective.

Results of the Study

The following tables reflect the positive (Table 2) and negative factors (Table 3) as reported by the sample. Common definitions are assumed for all terms, although respondents perhaps had differing understandings of these common terms, e.g., insufficient resources could mean budget shortfalls, personnel shortages, insufficient physical facilities, or a combination of all.

These results are consistent with similar studies that looked specifically at work compensation. Total work compensation has an influence on worker motivation, but it is not a significant factor affecting the behaviors that lead to measures of performance for knowledge workers in the federal workforce. The factors that are most influential are intangible, emotion-based, and intrinsic. The top 5 positive factors—meaningful work, belief in mission, sense of public service, opportunity to advance, and relationship with coworkers—are all highly personal and defined by the individual (Table 2). Conversely, the five most influential negative factors—insufficient resources, the "bad manager," a perception of a lack of support from managers, an unwillingness to deal with substandard performers, and the difficulty of the daily commute (Table 3)—are principally influenced, if not defined, by external actors.

TABLE 2. POSITIVE FACTORS

Rank	Top Positive Factors
1	Meaningful work
2	Belief in mission
3	Public service
4	Opportunity to advance
5	Relationship with coworkers
6	Relationship with supervisor
7	Personal work ethic
8	Education benefits
9	Great people
10	Flexible workplace policy
11	Empowerment
12	Organizational values
13	Teamwork
14	Supportive management
14	Recognition by others
16	Total compensation
17	Equitable awards policy
18	Job security

TABLE 3. NEGATIVE FACTORS

Rank	Top Negative Factors
1	Insufficient resources
2	Bad managers
3	Lack of management support
4	Unwillingness to deal with substandard performers
5	Difficult commute
6	Ineffective technology
7	Lack of planning
8	Lazy coworkers
9	Abusive supervisors
10	Lack of teamwork
11	Lack of promotion opportunities
12	Corruption in the workplace
13	Management resistance to change
14	Negative organizational culture

Conclusions

This group of federal employees expressed a preference for intrinsic (internal) factors. This is consistent with PSM Theory. Conditions that have the greatest negative effect appear to be those in which the workers have no direct control, e.g., how managers deal with substandard performers, the quality of supervisors, and the sufficiency of resources.

Implications

Regrettably, this study does not help Drucker's search for "one right way to manage people." As previously discussed, emotional-uncontrolled (contingent rewards) and mixed theories appear to be the most relevant. This was most surprising as these two sections encompass relatively few of the major theories. Even more interesting, was the section logical-controlled (hygiene). In the model, this section includes the greatest number of discrete theories, which appear to have the least relevance. This result was unexpected by the author, who expected factors consistent with Equity Theory to dominate. However, the expected key words, e.g., fairness, equality, justice, deserved, were scarce in the responses. This suggests that the subjects believe that either the current environment is equitable and does not influence their performance or that equitability is not a significant factor.

The results of this study also support the assertion that Maslow's Hierarchy of Needs, Herzberg's Two-factor Theory, and McGregor's Theory X/Theory Y are highly relevant to this population and to business in general.

Maslow. Since employment satisfies physiological and safety needs, love/belonging (relationships with coworkers, relationship with supervisors), esteem (opportunity to advance, empowerment) and self-actualization (belief in mission, meaningful work) become more important.

Herzberg. The Two-factor Theory asserts that motivators and de-motivators are mutually exclusive sets of factors. This research supports this assertion. A weak argument can be made that some of the factors are not true opposites, but are strongly related, e.g., great people—lazy coworkers, relationship with supervisors—bad managers; however, further investigation would be needed to support this argument.

McGregor. These findings suggest that public sector knowledge workers are self-motivated and will perform at the highest possible level when barriers to performance are absent. This is consistent with the Theory Y assertion that employees will seek out and accept responsibility, exercise self-control and self-direction, and will work well given the right conditions.

Implications for Practice

The author believes that strategic leaders should eschew the common approach of attempting to develop programs and policies to motivate the workforce, or at least any workforce similar to this population. Leaders cannot force motivation. There is no causal relationship. Leaders can mold an environment that allows workers to motivate themselves, but typical attempts to extrinsically motivate workers are counterproductive. The approach or philosophy of the leadership, as Sprenger (2007) suggested, should be to concentrate their time and resources on identifying and developing programs and policies that eliminate the negative aspects of workforce performance. There appears to be a greater return on investment for this approach.

Implications for Leaders

The supervisor-subordinate relationship, as Buckingham and Coffman (1999) suggest, appears to be a critical—possibly the most critical—relationship in the workplace. A poor supervisor-subordinate relationship is the leading cause of employee attrition

(MSPB, 2010, p. 2). On the positive side, the "relationship with managers" ranked as the sixth most important; on the negative side, "bad managers" ranked second. While a few respondents were concerned with anonymity of answers, many more reportedly shared their responses with supervisors during annual appraisal feedback sessions. Supervisors should consider a similar discussion with all subordinates. The exchange of perceptions may improve the supervisor-subordinate relationship.

Implications for Human Resources Organizations

If agencies insist upon individual performance evaluations—a position not supported by the author—agencies should consider implementing a 360-degree performance evaluation system instead of the traditional supervisor-only system. While a recent poll of federal workers by *Federal Times* ("How Should the Job Performance...," 2010) indicates that only 19 percent of federal workers believe these evaluations to be effective (likely as a method to identify a "bad manager"), a large body of anecdotal evidence suggests that 360-degree feedback systems are effective in, at a minimum, bringing poor supervisory performance to the attention of senior management. The single viewpoint of a biased, inattentive, or English-challenged supervisor may, in some cases, paint a false picture of employee performance.

However, be aware that in industry, the general acceptance of 360-degree evaluations is diminishing. The common belief appears to be that these evaluations are useful, but very expensive; and the measured increases in performance and profitability cannot justify these costs. While federal agencies are cost-constrained, they are not constrained by the profit motive. Such 360-degree evaluations may be an appropriate cost of doing business, especially in organizations where the public perception of high performance is critical.

Final Thoughts

The acquisition community is dominated by knowledge workers. These highly educated, high-skilled workers are self-managed and self-motivated. The traditional management approaches that appeared effective for the assembly-line workers of yesteryear are counterproductive when applied to the knowledge-based workforce. The monumental challenge for today's leaders is to abandon the management practices of the last 50 years, which to some are counterintuitive and fraught with uncertainty, and to embrace a theory that is still emerging. Extrinsic-based attempts to "motivate the workforce," despite conventional wisdom, are ineffective. Pay

for performance, bonuses, and even traditional performance evaluation systems, in the opinion of this author, are anachronisms.

When Thomas Paine said, "lead, follow, or get out of the way," he did not have the acquisition community in mind, but his admonishment is appropriate for today's leaders. The recipe for "doing more without more" is a simple one—one part solid, insightful leadership and two parts "getting out of the way."

Author Biography

Dr. David E. Frick is the senior advisor to the Defense Intelligence Agency's acquisition executive. He has 35 years of federal service, 15 of which were in the acquisition community. A retired noncommissioned officer and first sergeant with over 21 years of active duty in the U.S. Army, Dr. Frick holds Level III Defense Acquisition Workforce Improvement Act certification in program management, is a graduate of the U.S. Army War College, is a Project Management Professional, and holds a Doctorate of Business Administration from Girne American University.

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REQUIREMENTS AND COST STABILITY: A CASE STUDY OF THE F/A-18 HORNET PROGRAM

CDR Jay D. Bottelson, USN

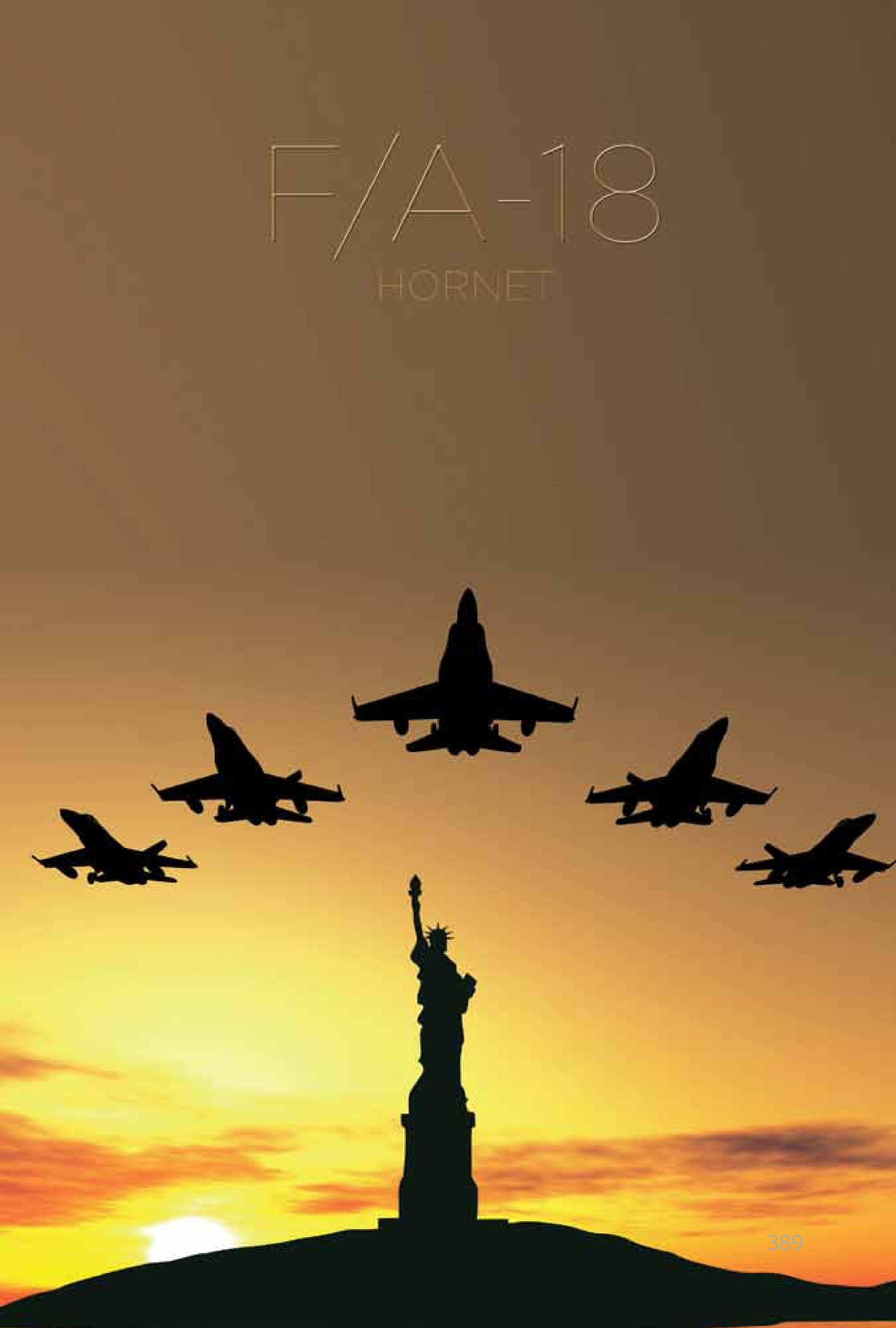
Most government and industry leaders involved with Department of Defense acquisition programs emphasize the importance of requirements and cost stability. However, despite all the stated support for program element stability and acquisition reform, frequent changes are experienced in acquisition programs that affect the final end product in terms of changes to unit design, number of units procured, system and subsystem capability, as well as affecting the overall cost of the program. This study analyzes the U.S. Navy's F/A-18A model to identify requirements changes; discern the reasons for change and the impact the resultant change made on the program (funding, schedule, capacity, etc.); and develop recommendations for limiting requirements creep, instability, and cost growth in future programs.

Keywords: *Acquisition Reform, Cost Growth, Requirements Stability, Requirements Creep, F/A-18 Hornet*

image designed by Harambee Dennis »

F/A-18

HORNET



"Among the changes made in the acquisition process in the last 20 years have been the greatly increased emphasis on Program Management, with capital letters. It could be noted that there seems to be a fair degree of correlation between that growth in emphasis with severity of the acquisition problem in terms of lengthened schedules and increased costs." (Spangenberg, 1981)

—George Spangenberg

Ironically, the most successful modern U.S. Navy aircraft began its life as a U.S. Air Force prototype. Therein lies the lineage of the F/A-18 Hornet. Indeed, the F/A-18 evolved from what can only be termed as a bizarre set of circumstances, tracing its beginnings back to the 1960s when the Air Force began looking for a lightweight fighter (Jenkins, 2000). By the mid-1970s, the Navy and Air Force were directed to work together and field a common lightweight fighter. Following a fly-off between the final two competing prototype aircraft, the Air Force chose its champion, which ultimately became the F-16 Fighting Falcon. At the time and inexplicably, the Navy demurred and chose the loser of the competition.

This article examines the topics of acquisition reform, requirements stability, and cost growth to determine the forces behind changes in major acquisition programs and what drives the changes—threats, technology, schedule, budget, or performance. While acquisition reform presently gets plenty of headlines, it has been an issue in the defense arena for years, as highlighted by the ongoing annual assessments of defense weapon programs by the Government Accountability Office (GAO, 2009). Yet despite the stated desire for requirements stability, frequent changes are experienced in acquisition programs that affect the final end product in terms of significant changes to unit design, number of units procured, system and subsystem capability, and unit costs to name but a few variables.

This study scrutinizes the initial fielded version of the Hornet, the F/A-18A, as a basis for study of the acquisition process and the requirements and capabilities changes that occurred between program approval and final product fielding. It will investigate why the F/A-18 was needed and the timeline for development, what the initial program requirements and cost estimates were, and what changes and adjustments were made. In examining these changes and adjustments, it delves into the causes and effects, namely why changes were necessary and what were the costs of the changes.

Finally, this article attempts to analyze and suggest a means for improving future program performance by identifying these past concerns. Specifically, it will attempt to discover the reason and amount of change from the initial plan in terms of time, cost, or product performance and capability. Additionally, it will categorize the impact of the changes on the program and develop lessons learned and recommendations for limiting requirements creep, instability, and cost growth.

Preparing for Launch

For a number of years, the Navy moved along toward filling its fleet of fighter aircraft with the highly capable F-14 Tomcat. But in 1971, the deputy secretary of defense, following the recommendations set forth in the Five Year Defense Plan, limited the Navy to only 313 F-14A fighters (F-18, 1975). At about the same time, the Air Force opened competition for design of a lightweight fighter. In mid-1973, the Department of Defense (DoD) and Congress placed strong pressure on the Navy for significant cost increases occurring in the F-14 fighter program. Additionally, Congress felt that the Navy should pursue a lightweight fighter as well, and the secretary of defense directed the Navy to assess the Air Force lightweight fighter designs (Jenkins, 2000). By the spring of 1974, two prototypes were ready for test flights—the General Dynamics YF-16 and the Northrop YF-17 (Kelly, 1990).

The Navy and Air Force both ultimately battled back-and-forth with the DoD over what they felt their needs were, and what DoD wanted them to have. The Air Force abruptly changed course and attempted to make the lightweight fighter effort go away by underfunding it, while a Navy fighter study group recommended several variants of the F-14 without the expensive Phoenix air-to-air missile (Stevenson, 1993). Despite its efforts, the Air Force was thwarted when the Office of the Secretary of Defense (OSD) decided to procure the YF-16 lightweight fighter for the Air Force. This was done by inserting funding in the Fiscal Year (FY) 1975 budget request sent to Congress in January 1974—1 month before the YF-16 conducted its first test flight (Stevenson, 1993).

In spite of direction from both Congress and DoD, the Navy released a Presolicitation Notice (PSN) to industry for its own lightweight fighter—the VFAX (V-fixed wing, F-fighter, A-attack, and X-experimental). However, Congress turned it down in August 1974 and placed it under a new program name called the NACF, or Navy Air Combat Fighter (F-18, 1975). As the Air Force continued toward acquisition of its new fighter, in September 1974 the Joint

Committee on Appropriations weighed in on this issue. The committee directed that the Navy would make appropriate modifications to the winner of the air combat fighter competition (Stevenson, 1993). This process to achieve commonality between the Services for their lightweight fighter needs made as much sense then as it does today because it would reduce overhead and simplify support issues. Unfortunately, as the late Senator Barry Goldwater observed at the time, "the only way…to get the Navy and Air Force to agree on a common fighter aircraft, is to…lock Navy and Air Force designers in the same room until they could agree…" (F-18, 1975).

When the YF-16 was announced as the winner of the Air Force lightweight fighter competition in January 1975, the Navy was not happy. According to Gaddis (2003), too much modification was required to "naval-ize" the aircraft, such as widening the distance between the rear landing gear, adding a keel, strengthening the airframe and all landing gear, and installing a tailhook—all to accommodate catapulting and arrested landings on aircraft carriers at sea. This would essentially result in a new aircraft that would definitely not have the commonality that Congress and others desired, and would weigh considerably more as well. Consequently, the Navy requested and received approval to develop the YF-17, the loser of the Air Force fly-off competition, and "[i]n a rare bout of bureaucratic honesty, …redesignated the aircraft F-18 in recognition of the substantial differences" (Jenkins, 2000).

"It is my opinion that the Air Force with the F-16 and the Navy with the F-18 find themselves today in the position of developing an aircraft for which neither had an original requirement. This doesn't mean each service cannot use these aircraft… Fortunately, the services have great flexibility which enables them to survive our collective, but sometimes not too wise, political wisdom."

—Senator Barry Goldwater
Statement to the Senate Appropriations
Committee, October 21, 1975

Initial Vector–Requirements and Cost

When it came time for contracts to be written for the development of the F-18, the Navy program manager called for something

unique at the time. Newly hired from the National Aeronautics and Space Administration, he called for specifications written into the contract for reliability in addition to performance. Previously, reliability had been addressed in contracts as goals, but never as specifications. When finalized, the contracts indeed captured the first ever agreement by a contractor to deliver reliability, maintainability, and performance (Kelly, 1990).

Those first contracts were issued in January 1976 for development and production for the first 11 planes. However, there were plans to deliver three versions of the aircraft—an F-18 fighter and A-18 light attack aircraft for the Navy, and dual-purpose aircraft for the Marine Corps that was very close to the F/A-18 that was finally fielded (Kelly, 1990). Initially, 780 aircraft were planned to go to the Navy and the Marine Corps. Some exceptional engineering and development of a dual-use radar for both air-to-air and air-to-ground use allowed the F-18 and A-18 designs to merge. As a result, the Hornet began to be called the F/A-18 in 1980, and was fielded in two versions: the single-seat F/A-18A and the two-seat F/A-18B (Jenkins, 2000). Initial operational capability (IOC) was scheduled for 1983 (Dyer, 1981, p. 13).

As previously stated, this article examines the F/A-18A model, which was developed, produced, and delivered from FY1975 to FY1985. During this timeframe, 371 total F/A-18A aircraft were delivered before the changeover to production of the next model—the F/A-18C. Additionally, 41 of the F/A-18B versions were delivered during the same period. Foreign military sales of F/A-18A and B versions were also produced and sold to Australia (52 aircraft), Canada (115 aircraft), and Spain (30 aircraft) during the same period (Jenkins, 2000).

The requirements, or performance standards, for the F-18 were initially described in the PSN of June 1974. The PSN described the initial, or threshold, requirements as well as the final, or goal, requirements. (Goal requirements are currently referred to as objective requirements.) Though all requirements are important, ultimately some can tend to be more important than others. However, several requirements proved difficult to attain during development and flight testing, such as operating range (specifically how far the aircraft could fly on internal fuel), acceleration, and overall aircraft weight (General Accounting Office, 1980a).

The threshold operating radius for the F-18 was 400 nautical miles (NM), with a goal of 550 NM. It was to be able to accelerate from 0.8 Mach to 1.6 Mach in 120 seconds at 35,000 feet threshold, and 80 seconds goal. Finally, it was to have gross takeoff weight of 30,000 pounds or less (Stevenson, 1993). These three performance requirements were not the only ones to cause problems, but they

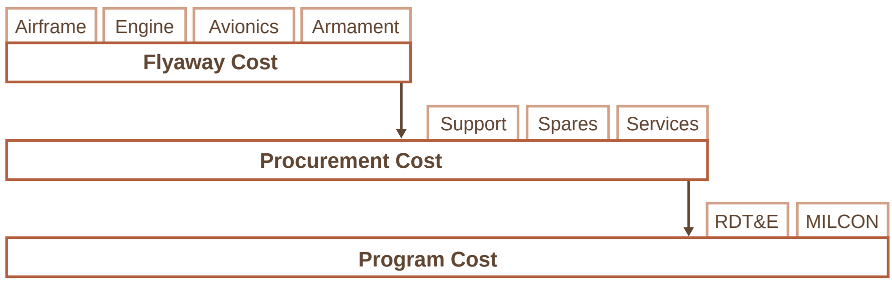
will be the main focus within this article due to their significance for fighter aircraft. In addition to performance concerns, cost growth caused just as much apprehension then as it does today.

When the Defense Systems Acquisition Review Council approved full-scale development of the F-18 in December 1975, the desired flyaway design-to-cost goal was $5.6 million in FY1975 dollars (Cooper, 1978). The first quarterly reports for the F-18, titled Selected Acquisition Reports, or SARS, began shortly thereafter. SARs were transmitted to Congress to report on the progress and cost estimates of DoD major acquisition programs. The first report on the F-18 (Office of the Under Secretary of Defense, 1976) stated that:

> The initial F-18 SAR...provides for a program of 11 R&D and 800 production aircraft at an overall cost of $12,831.1M, comprised of $8,005.6M in FY 1975 constant dollars and $4,825.5M in escalation, based on an average annual rate of 5.2%. This equates to a FY 1975 constant dollar program unit cost of $9.871M and an escalated unit cost of $15.821M. (p. 2)

Costs for major aircraft acquisition programs can be classified in three ways: flyaway cost, procurement cost, or program cost. These costs are depicted in the Figure. Flyaway cost includes the basic airframe, the engine, avionics, self-contained armament, and any equipment furnished by the government to the contractor for inclusion in the aircraft. Procurement cost takes flyaway cost and adds support and training equipment, technical data and publications, technical services provided by the contractor, and initial spare parts required. Program cost then takes procurement cost and further adds research and development and any military construction costs to reach a total acquisition cost.

FIGURE. ACQUISITION PROGRAM COSTS



A problem that exists with expressing cost in three different ways is that it can get very confusing to those charged with oversight of the complete program. For example, the cost that seems

most often described in congressional testimony reviewed for this study was flyaway cost. While not truly a misrepresentation, flyaway cost does not tell the complete story. As the table shows, flyaway cost can play down the true cost of the program effort, sometimes by as much as 50 percent.

TABLE. MAJOR AIRCRAFT ACQUISITION PROGRAMS—THREE MAIN COST CLASSIFICATIONS

	FY77 Budget		FY78 Budget		FY79 Budget	
	FY75 $ M	**TY $ M**	**FY75 $ M**	**TY $ M**	**FY75 $ M**	**TY $ M**
Flyaway	6.14	10.33	6.13	10.21	6.33	11.8
Procurement	8.19	13.71	8.15	13.52	8.33	15.3
Program	9.87	15.82	9.95	15.8	10.16	17.6

Note. Adapted from *Congressional Research Service,* Report No. 78-224-F, December 15, 1978.
TY = Then year; $ M = Dollars (in millions)

As the SAR excerpt previously described, costs are mainly expressed as a combination of program costs and escalation costs. Program cost variance can be due to changes in quantity, changes in requirements or capabilities, inflationary or deflationary cost changes, contractor overhead rates, delivery date changes, or even foreign military sales (General Accounting Office, 1981). Current programs experience change mainly due to increased research, development, test, and evaluation costs, program growth costs, delay in delivery of initial capabilities, and decreases in planned quantities (Government Accountability Office, 2009).

Mid-Course Corrections—Causes and Effects

The F/A-18A program experienced cost growth relatively early in the development phase as well as throughout its production run until FY1985, when block changes were incorporated to upgrade the F/A-18A and B versions to C and D versions (Elward, 2000). However, early program growth was mainly due to a mismatch between the inflation rates the program office was required to use by OSD. Guidance from the Office of Management and Budget (OMB) directed OSD to use inflation rates from the economic assumptions contained in the President's Budget (General Accounting Office, 1981). For example, the March 1976 SAR listed a 5.2 percent rate, but the General Accounting Office found in 1980 that OSD inflation rates ranged from 5.4 percent to 6.3 percent. Yet for the same time period, the Bureau of Labor Statistics calculated a 13 percent

inflation estimate, and the Air Force derived a 19 percent aerospace industry inflation rate (General Accounting Office, 1980b).

This required use of low inflation rates had two detrimental effects. It made the Service appear to be understating program costs, and it made budgeting difficult. In one case, a Navy official stated that the FY1981 budget submission would have been 15 percent higher if the aerospace industry inflation rate had been used (General Accounting Office, 1981). This correlates to an explanation in the notes for the December 1980 SAR (Office of the Under Secretary of Defense, 1980).

> Program costs increased by $8,177.9M, from $29,712.3M to $37,890.2M, due to (1) the application of higher anticipated escalation rates in program outyears ($+451.0M), (2) procurement schedule stretchout ($+907.0M), (3) support increase as a result of revised basing plan and repricing of support program ($+728.7M), and (4) reestimate of the R&D and procurement programs ($+6,091.2M). Of the $6,091.2M estimating increase, $3,855.8M represents the difference between Government inflation projections and actual experience on the FY 1979-1981 production contracts and proposals. As a consequence, support purchases have been deferred and seven aircraft are being dropped from the FY 1981 buy. Both actions contribute significantly to the schedule and support purchases identified above. (p. 2)

An evaluation of the numbers just cited clearly reflects that 63 percent of the cost for the re-estimate of the R&D and procurement programs was due to the difference in inflation rate projections and actual costs experienced during previous years.

Another program cost, though not monetary, occurred in the form of reduced performance capabilities. During the flight test phase of development, there were demonstrated shortfalls in a number of key areas. The acceleration threshold of 120 seconds from 0.8 to 1.6 Mach described in the PSN was lowered to 110 seconds in the contract specification. At the first flight evaluation in March 1979, it took 156 seconds. By May 1980, the contractor achieved the acceleration in 116 seconds, but could not reach the target specification (Stevenson, 1993). Additionally, range thresholds were not met during the demonstration phase. Despite an operating radius threshold of 400 NM on internal fuel, the best range eventually achieved was 380 NM after significant work by the contractor and testing by both the contractor and the Navy (Jenkins, 2000).

In 1981, a report on the F/A-18 explained that OSD (and thus the Navy as well) had decided that "the demonstrated acceleration and

range were acceptable," despite being well short of threshold specifications (General Accounting Office, 1981). However, one cause for concern here in retrospect is why substandard performance of program thresholds and contract specifications was accepted. The perception given is that the F/A-18 was wanted at any cost, even with reduced performance. Quite simply, it was an instance of specifications not being met and then changed, or de-scoped, because they could not be met.

The F/A-18 was also nearly 2,000 pounds over its initial specification weight according to a General Accounting Office (1980) report. Some of this weight growth was due to combining the designs for the F-18 and A-18, as the attack variant was 144 pounds heavier than the fighter version. Nearly 500 pounds was added due to reliability and maintainability features, and another 1,300 pounds for engineering estimates to attain reliability and maintainability goals (General Accounting Office, 1980a). These goals were added after the PSN was issued as part of the new program manager's attempt to write reliability into the contract as well as performance. Although the specification called for a gross takeoff weight of 33,652 pounds, the weight of the aircraft demonstrated during evaluation was 35,363 pounds. Eventually, the Navy changed the weight specification because it became nearly 36,000 pounds (Stevenson, 1993). This is an example of requirements creep on an upward scope. So once again, a specification was changed to meet a design shortcoming.

Final Destination—Hitting the Requirements Target

Though the F/A-18A Hornet proved its worth in war and peace, it was a very different aircraft from what was initially envisioned, designed, and estimated for cost. Indeed, when evaluated in terms of schedule, cost, and performance, the F/A-18A only attained one of the three criteria to effective standards. The Hornet was produced with minimal slippage in terms of development and production timeline, delivering the first production model in April 1980, and the first aircraft to IOC in January 1983 (Boeing, n.d.). This compares extremely well with present day major programs, where only 28 percent manage to achieve IOC on time (Government Accountability Office, 2009).

Cost was an area where better execution should have been attained. The F/A-18A began as a $12.8 billion program ($8 billion for the base program and $4.8 billion for projected escalation costs) in FY1975. Ten years later, in FY1985, it had grown immensely to

become a $39.3 billion program. This was partly due to an additional buy of 566 aircraft that added $6.8 billion in base year dollars and $19.7 billion in actual and projected escalation costs, but that portion of the cost growth is not really a major concern in this case. However, the choice to purchase more aircraft, while it does raise the cost of the program, is certainly not indicative of program mismanagement, and can often lower the unit cost through economy of scale.

Escalation costs were the single largest factor for cost increases in the F/A-18A program, an observation made in nearly every General Accounting Office report on the Hornet. While the December 1985 SAR shows the percent of cost growth attributed to total adjustment for quantity as 99 percent, a quick calculation shows the growth of Actual and Projected Escalation under Current Estimate–Program Cost was over 400 percent (Office of the Under Secretary of Defense, 1985). Though it may appear that the Navy was grossly deficient in their budgetary management for allowing this cost growth, the culpability lies with the required use of OMB inflation rates that were lower than real inflation.

Lastly, while the F/A-18A became a top-performing fighter/attack aircraft, the Navy made tradeoffs during development and accepted less performance than was originally specified in both the PSN and the contract. The Navy approved reductions to the contract specifications of 9.4 percent for range and 11.2 percent for level flight acceleration (General Accounting Office, 1980a). Additionally, it was forced to change the weight specifications when engineering and design, as well as the requirements for reliability and maintainability, caused the weight of the aircraft to grow beyond contract specifications.

Post-Flight Debrief—Finding and Fixing Gripes

On the whole, the F/A-18A program had several successes. First, it was produced without major adjustments to the development and delivery schedule. In fact, it went from contractor selection to the first-delivered production model in just under 5 years. Second, it featured the first instance where a contractor was tasked to deliver reliability, maintainability, and performance as part of the contract. This was a fair achievement for the F/A-18 in general. Though reliability and maintainability exceeded expectations and significantly reduced life-cycle costs, it also caused the overall system weight to increase. Finally, it achieved all this while undergoing a number of significant engineering changes, such as merging the F-18 and A-18 models into a single aircraft and developing a next type of radar.

Thus, from a program management perspective, the F/A-18A was exceptionally well-managed.

Conversely, the study that formed the basis of analysis for this article identified two key problems experienced between concept and fielding of the final product that are causes for concern. The first issue was cost growth due to "uncontrollable factors," as the General Accounting Office (1980b) report called them. As discussed previously, escalation cost increases driven by inflation rates were a key factor in overall cost growth. Yet the inflation rates used by the Navy were stipulated by OSD, as directed by OMB (General Accounting Office, 1980b). This issue was well documented in General Accounting Office reports from 1980 to 1998, and even for the latest version of the Hornet—the F/A-18E/F. The

1998 report stated that OSD-directed rates were still lower than the industry averages (General Accounting Office, 1998). Further review of more recent OSD guidance from February 2005 found guidance to use a 2.0 percent inflation rate for FY2006 (Office of the Under Secretary of Defense, 2005), while the Bureau of Labor Statistics shows aerospace industry inflation rates of 4.8 percent for aircraft manufacturing for the same period (U.S. Bureau of Labor Statistics, 2006).

Reduced performance capabilities are the second key issue. The F/A-18A was not able to meet several specified performance requirements during testing and demonstration. The choice presented was to either require the contractor to deliver the aircraft as specified—running a risk of cost and schedule overruns—or accept an aircraft with reduced capabilities. The Navy chose to accept the reduction in capabilities, and this was not a new instance of doing so. Historically, the Navy had similar problems with the F-14 Tomcat. A comparison of requirements to fielded capabilities revealed that the F-14 was 5,000 pounds overweight, failed to meet required

ranges, could not attain combat ceiling, and missed required maintenance and reliability as well as several other requirements. The F-14 did not meet its cost target either (F-18, 1975).

Accordingly, these two key issues can be considered as major "gripes" of enduring significance that need to be fixed. In aviation terms, a gripe is a maintenance problem that must be repaired before the aircraft can fly again. For the first gripe, as shown previously, OSD is using OMB inflation rates that are statistically too low. These inflation rates resulted in two substantial problems for the Navy. It made the Navy appear to be minimizing program costs, and thus caused the Navy to be suspect in the eyes of those charged with program oversight. It also caused problems for those responsible for preparing budgets, especially when they knew through past experience that the inflation rates would not meet real economic averages. At a minimum, Bureau of Labor Statistics inflation rates should be used. Ideally, Air Force aerospace industry rates should be used.

The second gripe focuses on requirements instability. It was expected that this study would show requirements being added after program start—a phenomenon referred to as requirements creep that is common in present-day programs. This was not the case. Instead, the instability was in the Navy and DoD holding firm on the specifications given to the contractor for delivery. As described previously, the F/A-18A came up short in a number of performance capabilities. For future programs, the Navy (or any Service for that matter) and DoD should decide before program start whether to accept performance standard shortfalls, and if so, how much variance is acceptable. This can be done by setting threshold and final performance goals that focus on attainment of a short range of parameters in the contract. For example, instead of specifying a top performance speed of 1.8 Mach, a range of 1.6 to 1.8 Mach is specified, with the lower number considered minimally acceptable and the higher number desired. To encourage the contractor to reach the higher standard, a scaled award fee or incentive fee could be used to reward the contractor for achievements above the minimum requirement. Alternatively, if there is not a desire to accept reduced performance, there must be consideration to how much additional time or cost growth, or even both, is acceptable to reach the desired performance standards.

Concluding Thoughts and Recommendations

The F/A-18A Hornet was born of a process that started with clean sheets of paper and a need to field a lightweight fighter to complement the F-14 Tomcat. Along the way, it went up against the highest levels of DoD and Congress, danced around the Air Force lightweight fighter competition, and emerged as a truly exceptional fighter/attack aircraft. The fact that it managed to stay on schedule and achieve IOC in light of the myriad engineering changes required to merge the F-18 and A-18 models is a testament to the dedication of the designers, engineers, and program manager.

However, in spite of these dedicated efforts, the program dealt with several major obstacles in the form of escalation/inflation costs and the inability of the aircraft to meet required specifications. Though the escalation costs did not detract from the ability to see the program through to the end, they gave the perception of a program that was not being managed properly and was being deliberately understated in order to continue to receive funding. Additionally, though the performance shortcomings did not stop the F/A-18A from achieving IOC and success in the fleet, concern remains over the reasoning behind accepting less than what was called for in the contract specifications.

To ensure the Services and taxpayers get the most for their money, the DoD needs to make two major changes: (a) revise the way it calculates and allows for inflation in major acquisition programs, and (b) base such calculations on more realistic values, such as those provided by the Bureau of Labor Statistics. It must also reevaluate and enforce established processes for situations where programs cannot meet specified requirements. This includes options of whether to agree to a lower performance level or to push for the established requirement to be met, with the acknowledgment and acceptance of the fact that it could take more time, incur a higher cost, or both. The words of George Spangenberg at the beginning of this article are as true today as they were when written in 1981. One additional quote of his bears repeating and brings this conclusion to a proper closing: “We should return to optimizing the naval aircraft acquisition process, rather than accepting compromise in the name of federal procurement standardization” (Spangenberg, 1981).

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BETTER SCHEDULE PERFORMANCE ASSESSMENTS DERIVED FROM INTEGRATED MASTER PLAN-REFERENCED SCHEDULE METRICS

David C. Bachman

The integrated master plan (IMP) provides a better structure than either the work breakdown structure (WBS) or organizational breakdown structure for measuring actual integrated master schedule (IMS) progress. The author posits that improved understanding of schedule performance and better identification of program risks result when an IMP structure is evaluated in addition to the earned value management-mandated IMS WBS structure. The article examines how the "Hit-Miss" index, baseline execution index, and critical path length index (CPLI) were used to evaluate the life-cycle performance of a 12-month, 900-task IMP program event. CPLI, the author concludes, is subject to interpretation and must be evaluated against four caveats: duration remaining, total float including schedule margin, schedule compression, and schedule avoidance.

Keywords: *Baseline Execution Index (BEI), Critical Path Length Index (CPLI), Earned Value Management (EVM), Integrated Master Plan (IMP), Integrated Master Schedule (IMS)*

image designed by Erica Kobren »

TECHNICAL/WORK BASELINE
1. DEFINE THE WORK
WHAT?
WBS
SOW
WHO?
RESPONSIBILITY
ASSIGNMENT MATRIX
WORK AUTHORIZATION
DOCUMENTS
SCHEDULE BASELINE
2. SCHEDULE THE WORK
WHEN?
INTEGRATED MASTER SCHEDULE
BUDGET BASELINE
3. ALLOCATE BUDGETS
100
40
15
HOW MUCH?
WORK/BUDGET AUTHORIZATION
PERFORMANCE MEASUREMENT BASELINE
TIME PHASED BUDGET PLAN
AGAINST WHICH CONTRACT
CONTROL
ACCOUNTS
September
2011
1 2 3
4 5 6 7 8 9 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30
NGA-CONSOLIDATION-DEADLINE

Since 2005, the National Geospatial-Intelligence Agency (NGA) has been tasked under the Base Realignment and Closure Act to consolidate all Washington, DC, metropolitan area facilities to a standalone campus currently called NGA Campus East (NCE) by September 11, 2011. The U.S. Army Corps of Engineers is currently managing the construction of NCE at the Fort Belvoir, Virginia, Engineering Proving Grounds (NGA, 2010). In addition to the NCE facilities, NGA has awarded additional contracts for the installation of communication, hardware, and software systems necessary to support the NGA mission at the new facility. This article examines the schedule performance reported from one of these contracts. The contract included full earned value management (EVM) implementation, and the reported data came from an Electronic Industries Alliance (EIA)-748B-compliant earned value management system (EVMS) (Government Electronics and Information Technology Association [GEIA], 2007).

The NGA program management team has included EVM as one tool to effectively manage program risk, technical scope, cost, and schedule. This contract's effort is built around an integrated master plan (IMP)[1] consisting of 11 major program events (PE),[2] 43 significant accomplishments,[3] and 201 accomplishment criteria.[4] From this IMP, a 6,000-line integrated master schedule (IMS) has evolved and continues to grow each month as the contract matures. A product-oriented work breakdown structure (WBS) and a corresponding EVM performance measurement baseline (PMB) resulted from the IMS. Integrated baseline reviews (IBR) were held in month 2 and month 6 of the program, and all IBR-related issues were resolved by month 13. The NGA EVM Center of Excellence (EVM COE) is responsible for program oversight and was challenged to create a set of pure, "straightforward" IMS metrics unrelated to EVM that would provide NGA leadership with accurate assessments of schedule progress.

The EVM COE augmented the contract-level acquisition, technology and logistics (AT&L) tripwire schedule metrics to improve their utility for assessing NCE contract schedule progress. Initially, the EVM COE examined reporting on all 14 of the Defense Contract Management Agency (DCMA)'s 14 point schedule assessment[5] metrics (Treacy, 2010) using the proposed 62-element Generally Accepted Scheduling Principle (GASP),[6] a quick-look schedule assessment (Meyer, 2010). Both proved to be far too detailed and intricate to address the straightforward challenge from NGA leadership. In 2006, DCMA standardized a set of EVM and schedule metrics for the Defense Acquisition Executive Summary (DAES) process known as the AT&L tripwire metrics. A subset of DCMA's 14 point schedule assessment metrics is included as AT&L tripwire met-

rics. The two primary and seven secondary metrics are designed to surface problems early for effective issue resolution (Kester, 2007). The baseline execution index (BEI) (which measures work progress) and the critical path length index (CPLI) (which measures efficiency associated with completing a milestone) are two of the secondary AT&L tripwire metrics directly related to schedule performance. Although not directly reported as a tripwire metric, the DCMA BEI tripwire briefing also reports the closely related "Task Hit/Miss Percentage" or the "Hit-Miss" index. These three metrics were the starting point for NGA's straightforward schedule assessment. Initially, the EVM COE computed these metrics only at the contract level and found them to have limited utility. Department of Defense (DoD) policy and the IMS data item description require the IMS to be delivered in a product-oriented WBS format (DoD, 2006). Since most of the contract's PEs cut across multiple WBS elements, computing WBS-related BEIs and Hit-Miss indexes revealed little about progress to the next PE. Considering that September 2011 was many months away, the critical path to that date was mostly controlled by EVM summary-level planning packages[7] or external milestones, making a contract-level CPLI at best misleading and unreliable. To accurately assess contract progress, the EVM COE computed IMS schedule metrics using an IMP structure and redefined the CPLI tripwire metric to include schedule margin.[8]

After reviewing an actual 12-month IMP PE life cycle, five metrics emerged that best defined schedule performance and status: contract-level Hit-Miss index, PE Hit-Miss index, contract-level BEI, PE BEI, and the PE CPLI. The EVM product-oriented WBS provided little insight into actual schedule performance because each reporting-level WBS element supported multiple PEs. The IMS data item description requires the IMS to be vertically traceable to the IMP, but it includes the caveat "(if applicable)" (DoD, 2005b). NGA contractors are required to map their IMS tasks and milestones to the IMP. This allows the schedule to be sorted by IMP PEs, IMP significant accomplishments, as well as the EVM product-oriented WBS and contract organization structures. Because the contract PEs were sequential in nature, the program management team's assessment focused on the next IMP PE or, in one case, the next two PEs because they were being completed in parallel. The EVM COE Hit-Miss index uses the AT&L Hit-Miss equation to measure the percentage of the current month baseline tasks/activities actually completed (or Hit) on or ahead of their baseline schedule (Figure 1). The EVM COE uses the AT&L tripwire BEI equation to measure the cumulative efficiency with which actual work is accomplished when measured against the baseline (Figure 2). Different from the AT&L tripwire equation, the NGA CPLI equation includes recognition

FIGURE 1. "HIT-MISS" INDEX EQUATION

$$\text{Task Hit - Miss} = \frac{\text{\# of THIS month's tasks finished on or ahead of their baseline schedule}}{\text{\# of THIS month's tasks to be finished in the baseline schedule}}$$

Note. This current period metric measures the percentage of current month baseline tasks/activities actually completed (or Hit) on or ahead of their baseline schedule (Hurley, 2007).

FIGURE 2. BASELINE EXECUTION INDEX (BEI) EQUATION

$$\text{BEI} = \frac{\text{\# of Baseline Tasks Actually Completed}}{\text{\# of Baseline Tasks Scheduled to be Completed}}$$

Note. This cumulative metric measures the efficiency with which actual work has been accomplished when measured against the baseline (Hurley, 2007).

of IMS schedule margin.[9] By dissecting the CPLI over the entire life cycle of an IMP PE, the program management team discovered that unlike the Hit-Miss and BEI metrics, they could easily influence the value of the CPLI metric (Figure 3). To truly understand a CPLI, four schedule caveats must be determined: duration remaining, float[10] and margin, schedule compression,[11] and schedule avoidance.[12] The following discussion presents a hypothetical schedule to review and explain these metrics and CPLI schedule caveats.

FIGURE 3. CRITICAL PATH LENGTH INDEX (CPLI) EQUATION

$$\text{CPLI} = \frac{\text{Remaining Duration + Float + Schedule Margin}}{\text{Remaining Duration}}$$

Note. Indexes the remaining duration to an IMP PE's current finish (*or to the original baseline finish, whichever is greater*) plus float duration plus schedule margin against the remaining duration. Float duration is always measured to the IMP PE's baseline finish date.

Method

The NGA schedule metrics and rationale for the four CPLI caveats can best be explained by reviewing the progress of a hypothetical schedule. Figure 4 is a hypothetical baseline schedule consisting of summary-level tasks, work tasks, one margin task, two PE milestones, and a start milestone. The network[13] schedule to PE No. 1 includes a critical path string and a high-risk path string, each networked to the PE No. 1's multistring margin task. Remember that

FIGURE 4. BASELINE SCHEDULE

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	NA	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	NA	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	NA	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	NA	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	0 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	0 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**70 days**	**0 days**	**5 days**	**0 days**
10	9	10-Day Work Task B1	Fri 1/15/10	NA	10 days	10 days	0 days	5 days	0 days
11	10	20-Day Work Task B2	Fri 2/12/10	NA	20 days	20 days	0 days	5 days	0 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	5 days	0 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	5 days	0 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	5 days	0 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	85 days?	85 days?	30 days?	0 days

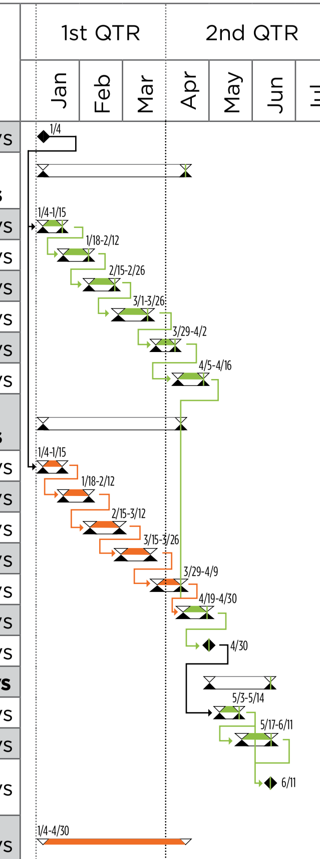

TABLE 1. SCHEDULE METRICS FOR HYPOTHETICAL SCHEDULE

Month of 2010	"Hit-Miss"[a]			BEI[b]			CPLI[c]				
	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
January	2	1	0.50	2	2	1.00	1.15	65	10	0	0
February	3	2	0.67	5	5	1.00	1.16	45	7	0	0
March	3	1	0.33	8	6	0.75	1.13	22	3	2	0
April	3	2	0.67	11	9	0.81	1.80	5	4	0	9
May	2			13							
June	1			14							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days. [a]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [b]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [c]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

the critical path is the longest path through a network schedule and may not represent the high-risk path. The high-risk string in this schedule has 5 days of total float. To demonstrate the NGA metrics and the CPLI caveats observed on the NGA contract, all tasks associated with the critical path will be completed on schedule, and the high-risk tasks will finish late to demonstrate how the metrics change as the schedule slips. These metrics and their color coding are summarized in Table 1.

NGA Schedule Metrics

Hit-Miss Index, BEI, and CPLI. The January 29, 2010, schedule (Figure 5) and the January 2010 data (Table 1) highlight the basic calculations associated with the NGA schedule metrics. At the end of the first reporting period (January 29, 2010), two tasks were scheduled to be completed and both were completed. Since Task A1 finished on schedule, it counts as a "Hit" for the Hit-Miss index and as a completed task for the BEI. Task B2 finished 3 workdays late, but still during the reporting period so it counts as a "Miss" for the Hit-Miss and as a completed task for the BEI. The Hit-Miss index is 1 ÷ 2 = 0.50, and the BEI is 2 ÷ 2 = 1.00. Although the high-risk path slipped, it has not yet slipped onto the critical path. So the IMS critical path to PE No. 1 is still controlled by the critical path string (0 float days) and the margin task (10 days). The January 29, 2010, schedule task—duration remaining check—shows that 65 workdays

FIGURE 5. JANUARY 29, 2010, SCHEDULE: "HIT-MISS" INDEX, BEI, & CPLI

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
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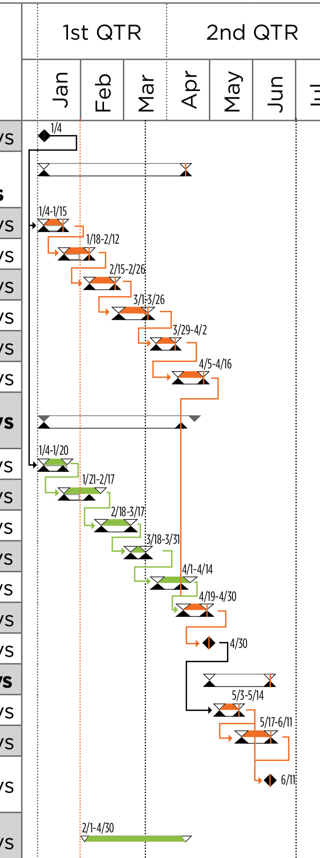
4	3	20-Day Work Task A2	Fri 2/12/10	NA	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	NA	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	0 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	0 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**73 days**	**3 days**	**2 days**	**3 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	NA	20 days	20 days	0 days	2 days	3 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	2 days	3 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	2 days	3 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	2 days	3 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	65 days?	65 days?	30 days?	0 days



remain until the PE No. 1 baseline finish date, resulting in a 1.15 CPLI [(65 + 0 + 10) ÷ 65 = 1.15] for the first reporting period.

CPLI Schedule Caveats

CPLI—duration remaining and total float. The February 26, 2010, schedule (Figure 6) indicates the high-risk path tasks have redefined the schedule's critical path. The February 2010 line entry in Table 1 lists the February 26, 2010, metrics. At the end of the second reporting period, all five tasks scheduled to be completed have been completed, resulting in a 1.00 BEI. Remember that the Hit-Miss index is a current period metric so the 0.67 value represents Task A2 and Task A3 finishing on schedule ("Hit") and Task B2 finishing 8 days late. With 45 days' duration remaining, the schedule's critical path is now defined by the slipping high-risk path tasks. To maintain the April 30, 2010, PE No. 1 baseline finish date, the margin task was reduced from 10 days to 7 days, resulting in a 1.16 CPLI [(45 + 0 + 7) ÷ 45 = 1.16]. Despite the fact that the high-risk path continues to slip, the CPLI showed a slight improvement, thereby demonstrating the need for the duration remaining caveat and total float caveat.

CPLI—schedule compression. The March 26, 2010, schedule (Figure 7) introduces schedule compression and an unfavorable BEI. The March 2010 line entry in Table 1 lists the March 26, 2010, metrics. The high-risk path tasks slipped an additional 6 days in March, and only Task A4 finished on schedule. Neither Task B3 nor Task B4 was completed, resulting in the Table 1 March 2010 Hit-Miss index of 0.33 and BEI of 0.75. If the schedule margin task's duration was reduced for the entire March 26, 2010, schedule slip (6 days), a yellow 1.045 CPLI would result. By compressing the Task B5's schedule by 2 days, the CPLI stays green because the float + margin remain at plus 3 days. This raises an obvious question: Can Task B5 be completed in 8 versus 10 days? It also highlights why schedule compression is a dimension that must be considered when evaluating the CPLI metric.

CPLI—schedule avoidance. The April 23, 2010, schedule (Figure 8) documents the final CPLI schedule caveat observed on the contract. The April 2010 line entry in Table 1 lists the April 23, 2010, metrics. Schedule avoidance occurs when a task is eliminated from the schedule, the IMS network logic is changed to allow a task to be deferred to a later program event milestone, or the IMS logic is changed to allow sequential tasks to be done in parallel. During April 2010, the overall schedule slipped an additional 7 days, making an on-time delivery of PE No. 1 impossible. To support an on-time

FIGURE 6. FEBRUARY 26, 2010, SCHEDULE: CPLI–DURATION REMAINING AND TOTAL FLOAT

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**3 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	3 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	3 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**78 days**	**8 days**	**0 days**	**8 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	2 days	8 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	2 days	8 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	2 days	8 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	45 days?	45 days?	30 days?	0 days

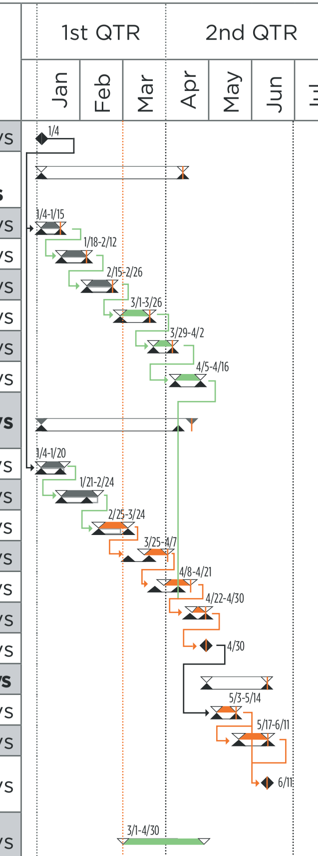


FIGURE 7. MARCH 26, 2010, SCHEDULE: CPLI–SCHEDULE COMPRESSION

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**7 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	Fri 3/26/10	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	7 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**82 days**	**12 days**	**0 days**	**12 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	26 days	6 days	0 days	14 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	0 days	14 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	8 days	-2 days	0 days	12 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	3 days	-7 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	NA	NA	0 days?	22 days?	22 days?	30 days?	0 days

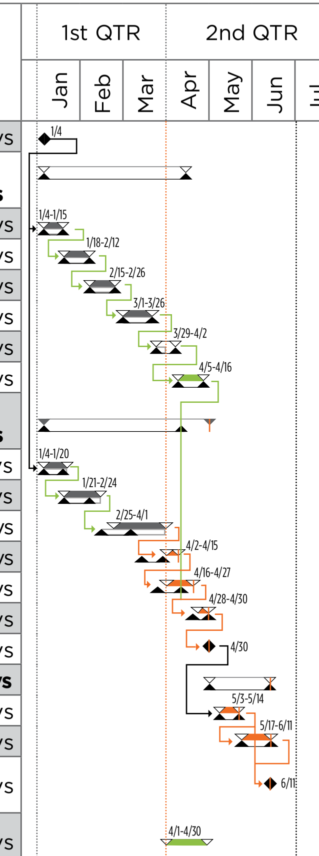
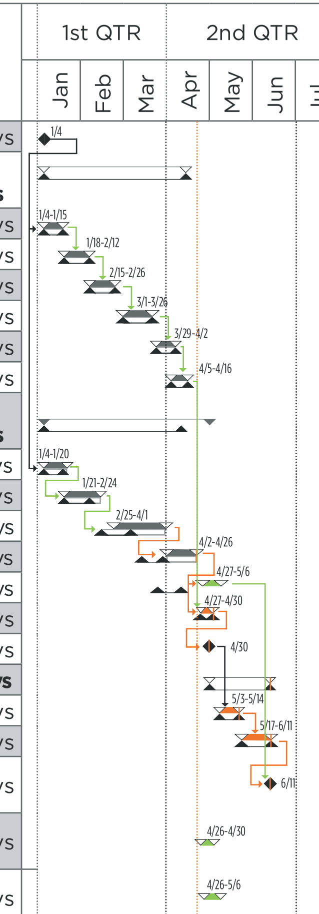


FIGURE 8. APRIL 23, 2010: CPLI—SCHEDULE AVOIDANCE

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**Fri 4/16/10**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	Fri 3/26/10	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	Fri 4/2/10	5 days	5 days	0 days	7 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	Fri 4/16/10	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**89 days**	**19 days**	**26 days**	**19 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	Thu 4/1/10	20 days	26 days	6 days	0 days	14 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	17 days	7 days	0 days	21 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	8 days	-2 days	26 days	19 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	4 days	-6 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	NA	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	NA	NA	0 days?	5 days?	5 days?	30 days?	0 days
22	22	Schedule Avoidance Check	NA	NA	0 days?	9 days	9 days?	26 days?	0 days



delivery of PE No. 1, completion of Task B5 is deferred to PE No. 2. This is done by deleting Task B5's task relationship with the schedule margin task and linking it only to the PE No. 2 milestone. Task B5's logic now bypasses PE No. 1, resulting in the avoidance of 9 days of duration remaining, 1 additional day of duration for the margin task, and a very favorable 1.80 CPLI [(5 + 0 + 4) ÷ 5 = 1.80] for PE No. 1. Without the Task B5 schedule avoidance, the PE No. 1 milestone slips 4 days, and the CPLI would be 0.56 = [{9 + (-4) + 0}/ 9]. This highlights why schedule avoidance is a CPLI metric caveat that must be evaluated.

Results and Discussion

The metrics and CPLI caveats discussed hypothetically in this article are computed and documented for the actual program in Tables 2, 3, and 4 at both contract and IMP PE levels. Tables 2, 3, and 4 document the contract schedule metrics for IMP PE-E, PE-F, and PE-G, respectively. The data reflect month 24 for PE-E, and month 25 for PE-F and PE-G. PE-G is the immediate successor event to PE-E and is being completed in parallel with PE-F, which is unrelated. Both PE-G and PE-F are baselined to finish during the first 2 weeks of month 35. The contract-level data tasks only include tasks through day 15 of month 35.

Many conclusions can be drawn from the data contained in Tables 2, 3, & 4 and the IMP strategy used to collect them. Conclusions associated with Table 2 are historic in nature and were confirmed with the NGA program manager and contractor. It is important to note that PE-E was completed on time. This was achieved by deferring some PE-E tasks to PE-G, and by eliminating other PE-E tasks that were not required. In the author's opinion, identification of the deferred and eliminated tasks may not have been discovered using traditional EVM WBS or Organizational Breakdown Structure (OBS) analysis strategies. Applying what the program management team learned from PE-E, pertinent questions arise regarding PE-F and PE-G trends and overall schedule performance. Seven key conclusions supported by this contract's data, metrics, and the IMP analysis strategy follow:

1. Unfavorable schedule trends. In all cases, unfavorable schedule trends are first manifested in the Hit-Miss index, then the BEI, and lastly in the CPLI.
2. Identification of work scope changes. IMP strategy clearly identifies work scope changes. The total number of PE–E tasks gradually increased from 1,109 tasks in month 14 to 1,171

TABLE 2. SCHEDULE METRICS FOR PROGRAM EVENT E

	Contract-Level Metrics[a]						Program Event E Metrics[a]										
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]				
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
13	7	1	0.14	45	12	0.27	0	0	0.00	8	4	0.50	1.06	221	12	0	0
14	47	11	0.23	92	40	0.43	27	3	0.11	35	22	0.63	1.11	197	22	0	0
15	65	16	0.24	157	81	0.52	39	7	0.18	74	39	0.53	1.12	177	21	0	0
16	160	40	0.03	317	148	0.47	84	18	0.21	158	88	0.57	1.07	158	11	0	0
17	153	12	0.08	470	202	0.43	76	4	0.05	234	113	0.48	1.06	133	10	0	0
18	226	31	0.13	696	314	0.45	129	15	0.12	363	174	0.48	1.03	113	3	0	0
19	238	66	0.28	934	508	0.54	159	35	0.22	522	277	0.53	1.11	93	10	17	0
20	148	54	0.36	1082	704	0.65	111	36	0.32	633	415	0.66	1.14	70	10	14	0
21	200	74	0.37	1282	925	0.72	123	50	0.41	756	574	0.76	1.04	50	2	11	0
22	207	63	0.30	1489	1130	0.75	79	33	0.42	835	690	0.82	1.00	30	0	3	0
23	297	71	0.27	1773	1492	0.84	61	24	0.39	886	803	0.90	1.00	7	0	73	25
24	169	72	0.42	1942	1573	0.81	12	9	0.75	900	884	0.98	1.00	0	0	0	53

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days.
[a]*Data based on end of Month 24 schedule.* [b]*"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25.* [c]*BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75.*
[d]*CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.*

TABLE 3. SCHEDULE METRICS FOR PROGRAM EVENT F

	Contract-Level Metrics[a]						Program Event F Metrics[a]										
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]				
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
22	190	63	0.33	1453	1130	0.78	30	9	0.30	102	63	0.62	1.04	265	11	0	0
23	257	71	0.27	1720	1492	0.87	24	9	0.38	126	96	0.76	1.04	242	11	0	0
24	132	72	0.55	1852	1573	0.85	31	5	0.16	157	117	0.75	1.05	222	11	0	0
25	99	30	0.30	1951	1689	0.87	22	7	0.32	179	143	0.80	0.99	203	-2	0	0
26	107			2058			18			197							
27	182			2240			39			236							
28	191			2431			50			286							
29	306			2737			67			353							
30	401			3138			74			427							
31	365			3503			69			496							
32	296			3799			68			564							
33	211			4010			59			623							
34	108			4118			30			653							
35	54			4172			35			688							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days.
[a]Data based on end of Month 25 schedule. Inconsistencies between Table 2 & Table 3 Contract Level metrics reflect incomplete tasks deleted from baseline during month 25. [b]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [c]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [d]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

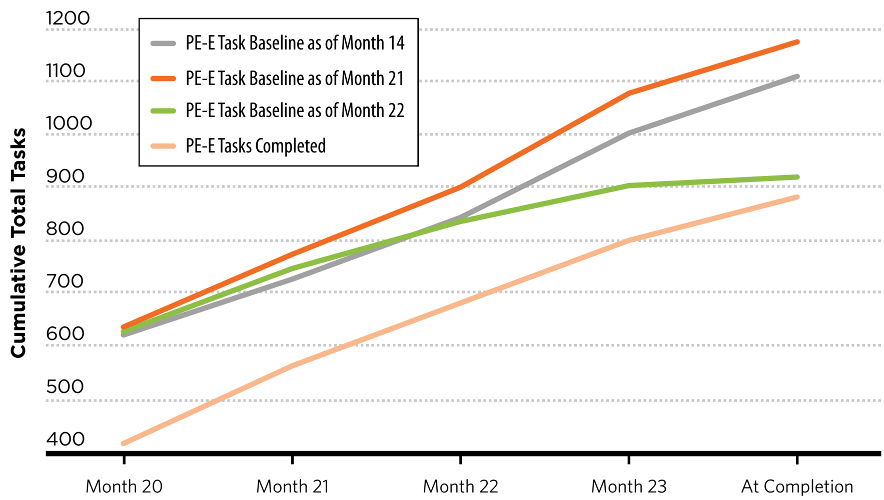
TABLE 4. SCHEDULE METRICS FOR PROGRAM G

	Contract-Level Metrics[a]						Program Event G Metrics[a]										
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]				
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
22	190	63	0.33	1453	1130	0.78	79	3	0.04	209	70	0.33	1.00	260	0	0	0
23	257	71	0.27	1720	1492	0.87	152	16	0.11	361	128	0.35	1.00	237	0	4	0
24	132	72	0.55	1852	1573	0.85	44	10	0.23	405	182	0.45	1.05	218	10	2	0
25	99	30	0.30	1951	1689	0.87	60	7	0.12	465	249	0.54	1.06	197	12	4	0
26	107			2058			78			543							
27	182			2240			130			673							
28	191			2431			120			793							
29	306			2737			210			1003							
30	401			3138			305			1308							
31	365			3503			267			1575							
32	296			3799			196			1771							
33	211			4010			121			1892							
34	108			4118			54			1946							
35	54			4172			6			1952							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days. [a]*Data based on end of Month 25 schedule. Inconsistencies between Table 2 & Table 4 Contract Level metrics reflect incomplete tasks deleted from baseline during month 25.* [b]*"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25.* [c]*BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75.* [d]*CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.*

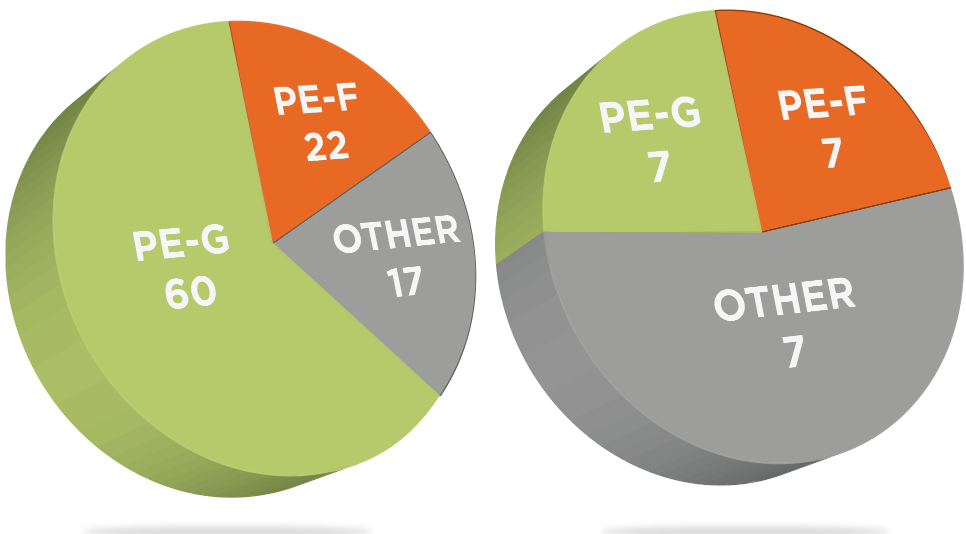
tasks in month 21. The program management team confirmed that these changes resulted from the conversion of EVM planning packages to EVM work tasks, and to the addition of new work resulting from contract changes. In month 22, the total tasks associated with PE-E were abruptly reduced to 924 tasks. The IMP strategy analysis approach clearly identified the descoping, and it was confirmed that the 257 associated tasks were either deferred or eliminated to support PE-E's month 24 delivery date (Figure 9). Additionally, comparing the Table 2 (based on month 24 data) contract cumulative tasks for months 22–24 with the same months on Tables 3 and 4 (based on month 25 data), the program management team can account for the permanent elimination of 90 PE-E tasks from the schedule.

FIGURE 9. PE-E WORK SCOPE CHANGES



3. IMP synergistic planning focus. The IMP structure allows for the current month contract-level tasks to be associated with the current IMP program focus. Tables 3 and 4 and Figure 10 show a total of 99 contract tasks baselined for month 25; 83 percent of these tasks are associated with either PE-F (22 tasks) or PE-G (60 tasks). This leaves 17 current month tasks that are not associated with either of the next two PEs. In and of themselves, the WBS and OBS structures would not easily support this type of assessment.
4. IMP synergistic performance focus. Closely related to conclusion 3, comparing the current month "Contract Tasks Hit" and the corresponding PE-F and PE-G "Hits" task values provides insight on the contract-level metric. Figure 10

FIGURE 10. IMP SYNERGISTIC METRICS



Month 25
Baseline Tasks Scheduled

Month 25
Baseline Tasks Completed

shows 30 of the 99-month, 25 contract-level schedule tasks were completed. Subtracting the 7 Hits from PE-F and the 7 Hits from PE-G leaves 16. So 16 of the 17 tasks not associated with either of the next two milestones were completed. This suggests the contract-level Hit-Miss index by itself may not be a good indicator for assessing PE-F or PE-G progress.

5. BEI measures schedule performance trends. Evaluation of the PE BEI trend can indicate if a schedule is improving. Review of the PE-E (Table 2) BEI metric from month 16 to month 18 indicates the number of cumulative tasks increased at a rate faster than the finished tasks were being completed. The month 16 BEI of 0.57 deteriorated to 0.48 by month 18, indicating a slipping schedule. This fact is also supported by the total float value, which eroded by 8 days during the same period. Like the EVM schedule performance index metric, the BEI eventually must improve to 1.00. This is clearly shown in the BEI improving from 0.48 in month 18 to 0.98 in month 24.
6. CPLI schedule compression an "early" tripwire. Schedule compression was first observed after the PE-E CPLI metric went from green to yellow. In month 18, PE-E's CPLI went from 1.06 (an NGA green value) to 1.03 (an NGA yellow value). In the following month's schedule, the metric returned to green (1.11) when the baseline durations of three future

critical path tasks were reduced by a total of 17 days. In many instances, the schedule compression magnitude was greater on the near-critical path strings than on the critical path string. The author attributes this to control account managers wanting to avoid the extra scrutiny associated with being on the critical path. The EVM COE makes no value judgment on the validity of the schedule compression; as such, the NGA CPLI equation (Figure 3) does not consider it. Schedule compression is a key caveat the program manager must consider when evaluating schedule risk. The author believes schedule compression is a critical indicator of pending schedule issues. In the PE-E schedule, schedule compression was first observed in month 19—3 months before the month 22 adjustment discussed in conclusion 2.

7. CPLI schedule avoidance "too late" tripwire. Schedule avoidance first appeared when it became apparent that PE-E, as it was originally baselined, could not be completed on schedule. During the final 30 workdays leading up to PE-E, 39 tasks originally associated with PE-E were remapped to PE-F. This allowed for the on-time delivery of PE-E. The impact of this can be observed in the month 23 "PT" column (Table 4), which denotes PE-G Tasks Baselined. The contractor confirmed that the disproportionate number of month 23 tasks (152) resulted from tasks being transferred from PE-E. Like schedule compression, the EVM COE does not consider schedule avoidance in the CPLI computation, but does report it as a CPLI schedule metric caveat. The program manager must make the final decision on the potential cost, schedule, and programmatic risk associated with eliminating work scope altogether or deferring work scope to a later IMP PE milestone.

Summary and Concluding Discussion

The EVM COE was challenged to create a set of schedule metrics that provide NGA leadership with accurate assessments of schedule progress. A better understanding of schedule performance and improved program risk identification were realized on this contract when NGA focused its schedule metrics on the IMP structure. While this study's positive results are based on a single contract, they justify additional research with a larger data set. The CPLI caveats qualify the CPLI tripwire metric, which could be easily misinterpreted without them. Considering this finding, additional research is warranted to justify requiring CPLI metric reports to include the caveats. NGA program managers have embraced the IMP structure and the metrics discussed in this article because they are straightforward, focus on near-term problems, and identify specific tasks needed to assess programmatic and schedule risk. This IMP approach, however, does not address cost. The EVM COE found that the IMP structures were so different from the contract's corresponding WBS and OBS structures that EVM cost and schedule data could only be correlated at the total contract level.

NGA has applied the techniques discussed in this article with mixed success on other NGA contracts. When the IMP and schedule margin were well-defined, the resulting schedule metrics were easily computed and meaningful. However, often the required IMP was poorly constructed and schedule margins were ill-defined. Schedule compression and schedule avoidance, to a lesser extent, were observed on many NGA contracts. The 438-page Government Accountability Office (GAO) *Cost Estimating Assessment Guide* lists only three IMP references and contains no discussion on how IMP is to be used (GAO, 2009). The EVM EIA-748B standard does not reference the IMP at all (GEIA, 2007). For the past 6 years, the National Defense Industrial Association (NDIA, n.d.) has identified schedule margin as an unresolved issue (Treacy, 2009; Berkey 2004). The community needs to create an IMP data item description and establish a best practice for implementing schedule margin to universally realize meaningful, straightforward schedule metrics based on this article's IMP approach.

The IMP structure augmented and provided more meaningful metrics for measuring near-term schedule performance then either the WBS or OBS structures; however, integrated program management requires cost, schedule, and performance metrics. This study highlights the value of adding an IMP structure to the IMS. The logical extension of this study would be to also require EVM data be mapped to the IMP structure.

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ENDNOTES

1. Integrated Master Plan (IMP)—The IMP is an event-based plan consisting of a hierarchy of program events, with each event being supported by specific significant accomplishments, and each accomplishment is associated with specific accomplishment criteria to be satisfied for its completion (DoD, 2005a).
2. Program Event—A program event is a program assessment point that occurs at the culmination of significant program activities: significant accomplishments and accomplishment criteria (DoD, 2005a).
3. Significant Accomplishment—A significant accomplishment is the desired result(s) prior to or at completion of a program event that indicates a level of the program's progress (DoD, 2005a).
4. Accomplishment Criteria—Accomplishment criteria provide definitive evidence that a specific significant accomplishment has been completed (DoD, 2005a).
5. Defense Contract Management Agency 14 Point Schedule Assessment—A set of standardized schedule heath and performance metrics used to evaluate integrated master schedules. The metrics included: logic, leads, lags, task relationships, constraints, high float, negative float, high duration, invalid dates, resources, missed tasks, critical path, CPLI, and BEI.
6. Generally Accepted Scheduling Principle (GASP)—A defense industry–Department of Defense initiative to produce valid and effective schedules. To meet GASP tenets, a schedule must be complete, traceable, transparent, statused, predictive, usable, resourced, and controlled.
7. Summary-Level Planning Package (SLPP)—An aggregation of work for far-term efforts, not comprised of detailed planning nor able to be identified at the control account level, which can be assigned to reporting-level WBS elements (DoD, 2006).
8. Schedule Margin—A management method for accommodating schedule contingencies. It is a designated buffer and shall be identified separately and considered part of the baseline. Schedule margin is the difference between contractual milestone date(s) and the contractor's planned date(s) of accomplishment (DoD, 2005b).
9. IMS Schedule Margin—There are differing opinions in the EVM community on the proper use and interpretation of IMS schedule margin[8] (DCMA, 2010; Price, 2008; NDIA, n.d.). Because most NGA contracts include schedule margin strategies, the EVM COE metrics include the use of schedule margin.
10. Float—Also known as total float and total slack. The amount of time a task/activity or milestone can slip before it delays the contract or project finish date (DoD, 2005b).
11. Schedule Compression—Schedule Compression is the difference between a task's baseline duration and the task's current duration. Microsoft Project calls this duration variance (Stover, 2007).
12. Schedule Avoidance—Schedule Avoidance occurs when a task's baseline logic is changed to bypass a measured milestone.
13. Network—A schedule format in which the activities and milestones are represented along with the interdependencies between work tasks and planning packages (or lower level tasks or activities). It expresses the logic (i.e., predecessors and successors) of how the program will be accomplished. Network schedules are the basis for critical path analysis, a method for identification and assessment of schedule priorities and impacts. At a minimum, all discrete work shall be included in the network (DoD, 2005a).

APPENDIX

List of Abbreviations and Acronyms

AT&L	Acquisition, Technology and Logistics
BEI	Baseline Execution Index
CPLI	Critical Path Length Index
DAES	Defense Acquisition Executive Summary
DCMA	Defense Contract Management Agency
DoD	Department of Defense
EIA	Electronic Industries Alliance
EVM	Earned Value Management
EVM COE	NGA Earned Value Management Center of Excellence
GAO	Government Accountability Office
GASP	Generally Accepted Scheduling Principle
GEIA	Government Electronics and Information Technology Association
IBR	Integrated Baseline Review
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
NASA	National Aeronautics and Space Administration
NCE	NGA Campus East
NDIA	National Defense Industrial Association
NGA	National Geospatial-Intelligence Agency
OBS	Organizational Breakdown Structure
PE	Program Event
PMB	Performance Measurement Baseline
WBS	Work Breakdown Structure

REIMAGINING WORKLOAD TASK ANALYSIS: APPLICATIONS TO TRAINING SYSTEM DESIGN

Dennis Duke, Dana E. Sims, and James Pharmer

Today's warfighter performs more complex, cognitively demanding tasks than ever before. Despite the need for more extensive training to perform these tasks, acquisition professionals are often tasked to reduce training budgets and identify optimal tradeoffs. Tools are available to help them make these decisions that provide empirical evidence of how performance and mission requirements will be affected by design decisions. This article offers insights into the utility of implementing a Workload Task Analysis (WLTA) early in weapon systems acquisition for the purpose of focusing on training system decisions, and provides a description of where WLTA occurs within the top-down functional analysis process. It concludes with several examples of how the WLTA results can be used to guide training development.

Keywords: *Workload Task Analysis (WLTA), Training Development, Top-Down Function Analysis, Mission Requirements, Performance Requirements*

image designed by Miracle Riese »


Training
analysis
analysis
analysis

A perfect storm has arisen in military training system acquisition. First, a great deal of attention is being given to cost overruns in major weapon systems acquisition by the Department of Defense (DoD). As a result, government officials are continually searching for ways to reduce budgets. Program managers are continually being asked to consider reducing training time to reduce costs, and while battlefield technology is becoming more sophisticated, it provides much greater capability in considerably less time. However, in many instances the technology is placing greater demands on warfighters by requiring a shift in how work is accomplished. In many cases, tasks are more sophisticated and time-sensitive than in the past. This shift in the type of work and speed of performance by the warfighter on the battlefield requires more training in knowledge-based, decision-making tasks than ever before. This type of training is more complex because it requires individuals to understand, integrate, and act swiftly on the information generated from weapon systems technology; thus, additional time to train warfighters for battle is needed although budgets seldom allow for it.

One solution to this perfect storm is to employ systems engineering much earlier in the acquisition process as advocated by Michael J. Sullivan, Director, Acquisition and Sourcing Management in testimony before the Panel on Defense Acquisition Reform, Committee on Armed Services, House of Representatives (Government Accountability Office [GAO], 2009). Numerous dimensions are inherent to systems engineering in the acquisition process, one of which involves a systematic evaluation of the type of work done by a human operator on a new weapon system with the intent to determine how best to design training solutions to support that work. This process is called a Workload Task Analysis (WLTA) and is incorporated as an element of an overarching process called Top-Down Function Analysis (TDFA). This methodology aligns with the revised DoD Instruction 5000.02 (DoD, 2008, Encl. 8), which stipulates that "… where practicable and cost effective, system designs shall minimize or eliminate system characteristics that require excessive cognitive, physical, or sensory skills; entail extensive training or workload-intensive tasks; result in mission-critical errors; or produce safety or health hazards" (DoD, 2008). This article suggests that if this process is effective for a weapon system design, it can also produce similar results for a training system.

Although WLTA is often done iteratively throughout the weapon systems acquisition process, this article is limited to how an early analysis can initially identify areas where warfighters experience the highest levels of workload that may negatively affect performance. The findings from conducting WLTA up front have the potential to not only increase operator efficiency and effectiveness by influ-

encing weapon systems design early in the acquisition cycle, but may also reduce weapon systems life-cycle costs. The design of the training system can be included as part of this cost reduction; accordingly, this article provides a concise definition, examples, and insight into WLTA and the basic steps required to perform a credible WLTA.

Fundamentals of Workload Task Analysis Methodology

Modern technology has vastly changed the way we do business and has improved our productivity by providing us with many more on-the-job capabilities. However, the technology is only productive when effectively employed by the human operator. This effective operation relies upon the cognitive capacity of individuals combined with their ability to operate the new technology to its fullest potential. This ability comes from a well-designed training program that provides the operator with pertinent information needed to effectively perform tasks on the job. Today, the amount and speed of information received during war combined with the complexity of the technology that military personnel employ to gather and interpret this information further compounds workload burdens on the individual.

Historically, WLTA has been used to predict potential performance bottlenecks and pinpoint where to focus the efforts of human factors engineers in helping them make informed decisions on new systems design. In numerous instances, operator workload, task time demands, and interface design issues affected the design of numerous platforms, from helicopters to airplanes, ships, and individual weapon systems (Aldrich, Szabo, & Bierbaum, 1989, pp. 65–80; Laughery & Corker, 1997). Recently, trends are re-emerging in military settings to investigate existing systems engineering processes and procedures much earlier in the acquisition program because of their impact on reducing overall life-cycle costs for major weapon systems (GAO, 2009).

Examining workload can assist analysts in determining the degree to which operators can successfully perform their job to meet mission requirements (Lysaght et al., 1989). To design a good system, the designer must comprehend the concept of workload and understand what "optimal" workload means to performance (Mitchell, 2000). Although a number of definitions of workload have been provided over the years, the overarching theory acknowledges that it is a multidimensional construct that considers the amount of effort (e.g., sensory, cognitive, or psychomotor) required or invested

by the individual in order to perform on the job (Aldrich et al., 1989; Nachreiner, 1995; Wickens, 1984). This performance is affected in part by (a) the demands of the environment where the task is performed (e.g., heat, danger), (b) the complexity of the task or the system in which the task is performed, and (c) the capability of the operator to satisfy those demands (Parasuraman & Hancock, 2001; Parasuraman & Rovira, 2005; Wickens, 2002).

In a WLTA effort, insight into how individuals gather and process information about task performance and the variables that affect cognitive decision making (e.g., environmental factors, task complexity, etc.) can be collected and analyzed through task network simulation models. These models provide useful human system performance information to human factors psychologists, systems engineers, and instructional system developers to allow for a myriad of design trade decisions. The power of these models lies in their capability to predict within a task flow where and when operators may not be able to perform specific tasks in a timely, effective, and efficient manner. This effectively assists analysts in determining targets of opportunity for developing an optimal performance solution. An example cited in a recent GAO report describes a situation that illustrates where WLTA may affect the design of weapon systems. The report (GAO, 2010) describes a scenario in a surveillance aircraft where operators who are responsible for processing, exploiting, and disseminating Intelligence, Surveillance, and Reconnaissance (ISR) data can only use collected intelligence data if the data are visible to them.

> Making ISR data discoverable in this way can be accomplished through meta-data tagging…For example, a camera may create meta-data for a photograph, such as date, time, and lens settings. The photographer may add further meta-data, such as the names of the subjects. The process by which information is meta-data tagged depends on the technical capabilities of the systems collecting the information. Most ISR systems do not automatically meta-data tag the ISR data when they are transferred from the sensor to the ground station for processing and exploitation because most of these systems were developed prior to DoD's emphasis on enforcing meta-data standards. Since the sensors on these legacy systems are not able to meta-data tag automatically, it is up to each of the military services to prioritize the cataloging of the ISR data manually after collection. (p. 5)

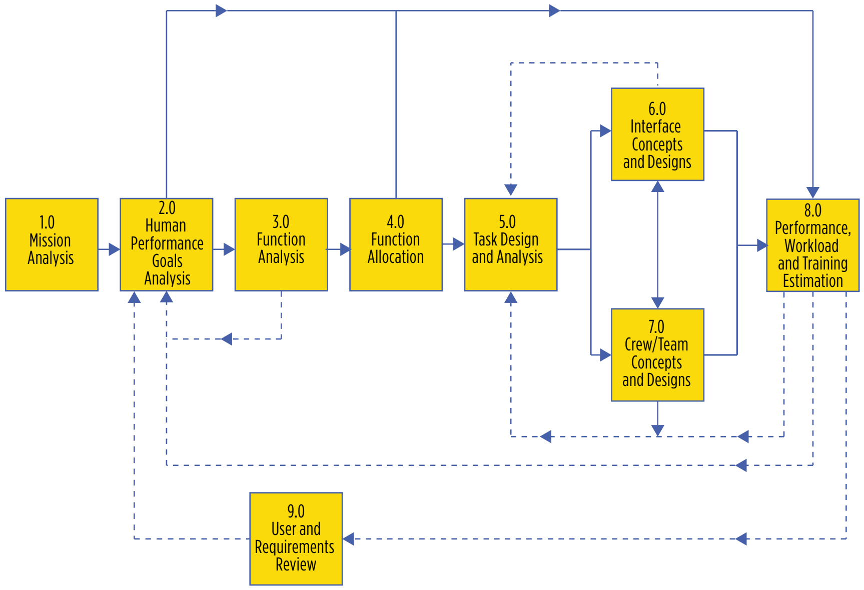
The solution, influenced by WLTA analysis findings, may involve designing software capabilities that automate these meta-data tags

and require the human operator to confirm the accuracy of the tagging. The training implications resulting from this design change involve the identification of specific knowledge and skills needed to operate this newly designed hardware and a determination of a training strategy for presenting this information to the operator. However, to fully understand where WLTA comes into play in the acquisition process, it is important to describe the overarching analysis process involved. This is known as the TDFA.

Understanding the TDFA Process

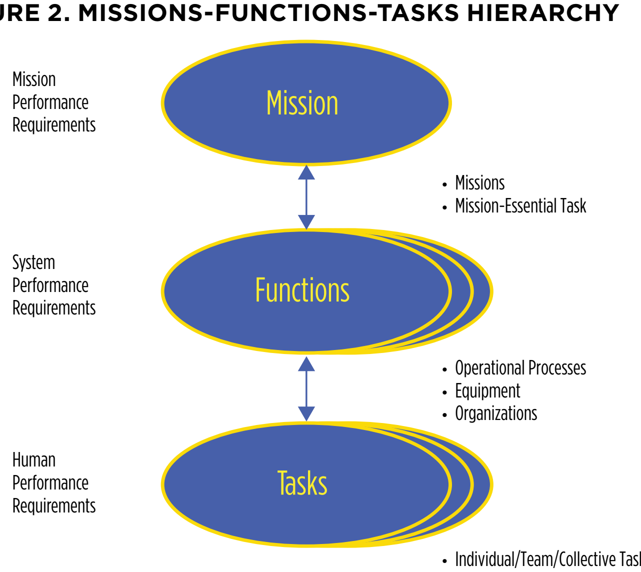
The initial assessment of any workload prediction methodology requires the conduct of a comprehensive mission/task/workload analysis (Aldrich et al., 1989). The TDFA methodology is a systems engineering approach that identifies mission requirements and provides a comprehensive capability for ensuring that the human performance requirements are incorporated into the systems engineering process (Dugger, Parker, Winters, & Lackie, 1999). The intent of the TDFA is to influence and refine system design throughout the acquisition process. The full TDFA methodology used in several naval aviation acquisitions involves nine phases or steps as shown in Figure 1 (Duke, Guptill, Hemenway, & Doddridge, 2006). However, only the analytical activity undertaken in the Mission Analysis (Phase 1.0), Function Analysis (Phase 3.0), and Task Design and Analysis (Phase 5.0) will be discussed in this article.

FIGURE 1. THE TOP-DOWN FUNCTION ANALYSIS (TDFA) PROCESS



In this TDFA model, the WLTA is included as the major component of Phase 8.0, Performance, Workload, and Training Estimation. However, the WLTA cannot be undertaken until critical hierarchical information about the weapon system's missions, functions, and tasks is available. In the Phase 1.0 (Mission Analysis), the external objectives or the "what" of the system performance are identified. This equates to the systems engineering "requirements analysis" described in American National Standards Institute/Electronic Industries Alliance 632, *Processes for Engineering a System* (ANSI/EIA, 2003). System functions, which are initially analyzed in Phase 3.0 (Function Analysis), describe "how" the system will achieve performance requirements. These system functions are then further decomposed into human and system tasks, which describe the qualitative and quantitative workload of individual, team, and crew operators and maintainers. This decomposition occurs in Phase 5.0 (Task Design and Analysis). Optimal design solutions based upon recommendations from the task decomposition are integrated during Phase 6.0 (Interface Concepts and Designs) and Phase 7.0 (Crew/Team Concepts and Designs) to ensure system-level optimization and compatibility. The results of the TDFA are then verified to see if human system integration is being adequately addressed in meeting weapon systems mission goals. Ultimately, the process provides a hierarchy for logically linking human performance (tasks) with the combatant commander's warfighting needs (missions) as shown in Figure 2 (Duke et.al., 2006).

FIGURE 2. MISSIONS-FUNCTIONS-TASKS HIERARCHY



The WLTA, which occurs in Phase 8.0 (Performance, Workload, and Training Estimation), uses information obtained in the previously mentioned TDFA phases. To gain an appreciation of the WLTA, a brief description of the mission, function, and task analysis phases of the TDFA model is provided.

Mission Analysis (Phase 1.0)

The Mission Analysis Phase of the TDFA serves to determine and document the overall purpose, objectives, and mission requirements of a weapon system. Initially, a weapon system's primary and secondary missions (e.g., Anti-Submarine Warfare, Anti-Surface Warfare, etc.) are determined and correlated with system mission tasks. The Universal Navy Task List or other Service task lists provide the basis for identifying the system mission tasks. Initial metrics are also established to measure results in the execution of missions. This involves creating Measures of Effectiveness (MOEs) and Measures of Performance (MOPs), which are used to determine the system's ability to support the achievement of an operational mission and the technical performance standards that a system must achieve to satisfy the MOEs, respectively (Chairman of the Joint Chiefs of Staff, 2003). MOPs also serve as high-level standards by which many systems operators will be evaluated.

The system constraints and boundaries, which may have an impact on training program design, are also identified in the Mission Analysis Phase. For example, in dealing with the acquisition of a training system for a new surveillance aircraft, one must determine if the scope of the platform (system) includes a ground station. If it does, then the training analysis must consider the infrastructure and all associated logistics associated with the ground station as well as that of the platform. Information about constraints and boundaries is usually obtained by analyzing its high-level mission objectives, which are found in acquisition-related publications such as the weapon system's Initial Capabilities Document, Capability Development Document, Performance Based Specification, and Office of the Chief of Naval Operations Instruction 1000.16K (2007). Once the overall purpose, objectives, and mission requirements are determined, it must be determined what the system must do to satisfy the mission requirements. This analysis is called a Function Analysis.

Function Analysis (Phase 3.0)

The goal of the Function Analysis Phase is to define performance at the level of detail where it is possible to design all subsystems or components needed to satisfy performance requirements. For example, if a mission requirement exists for weapon systems to perform surveillance, then the weapon system (e.g., an aircraft) must be

designed with a means to undertake the surveillance function (e.g., must have a radar system). Functions provide the means to align mission requirements to the specific system hardware and software. The Department of Defense Architecture Framework (DODAF) data model views, which are developed by mission system engineers, provide detailed hardware and software information about the functions performed by equipment embedded in the technical systems (e.g., radar system) comprising a weapon system (DoD, 2009). They also supply important information about the technical communication between the equipment (e.g., describe technical cues and responses of hardware and software tasks). The integrated product team (IPT) training team must train the human operator on how to effectively interface with the equipment and must ensure the operator understands how technical activities accomplish mission requirements.

Task Design and Analysis (Phase 5.0)

In the Task Design and Analysis Phase, analysts develop initial tasks that describe how humans will perform assigned system functions. During this phase, hardware and software tasks are linked with human performance. Information in this step usually comes from a stratified sample of subject matter experts (SMEs), who either have performed the tasks or are very familiar with how the tasks should be performed. One way to collect task information is to use critical-event scenarios where SMEs, using a flowchart, identify, describe, and document the individual tasks and subtasks they perform at their workstation during a mission. Each scenario should depict a unique mission area, which allows the SMEs to collect information about the different types of workstation tasks performed during different missions. The authors recommend that all technical publications and applicable reference workstation documents are made available to SMEs during this exercise. In cases where the SMEs are providing information based on their experiences with a legacy system, the legacy tasks are compared to the high-level notional functions, missions, and tasks obtained from the DoDAF model views and documented in the TDFA. As the new systems on the weapon system are developed, changes will be assessed and the functional architecture will be modified.

Undertaking a Workload Task Analysis

As stated previously, a WLTA effort provides insight into an operator's perceived level of effort to complete a task and the variables that affect decision making. The WLTA is conducted in

Phase 8.0 of the TDFA process. The information from the Mission, Function, and Task Design and Analysis Phases enables the WLTA analyst to understand the workload associated with a given task/mission. The workload activity is divided into time and information processing demands (e.g., visual, auditory, cognitive, and psychomotor [VACP]) so it can be examined from various perspectives. These perspectives assist the human factors psychologists, systems engineers, and instructional system developers to better analyze high-workload-demand tasks. The discussion that follows contains a brief description of the two types of workload data collected (i.e., time estimation, information processing estimation), and provides examples of potential training-related performance solutions to workload. These training solutions are not intended to be all-inclusive, but rather provide a starting-off point for any IPT training team to consider for its own platform.

Time Estimation

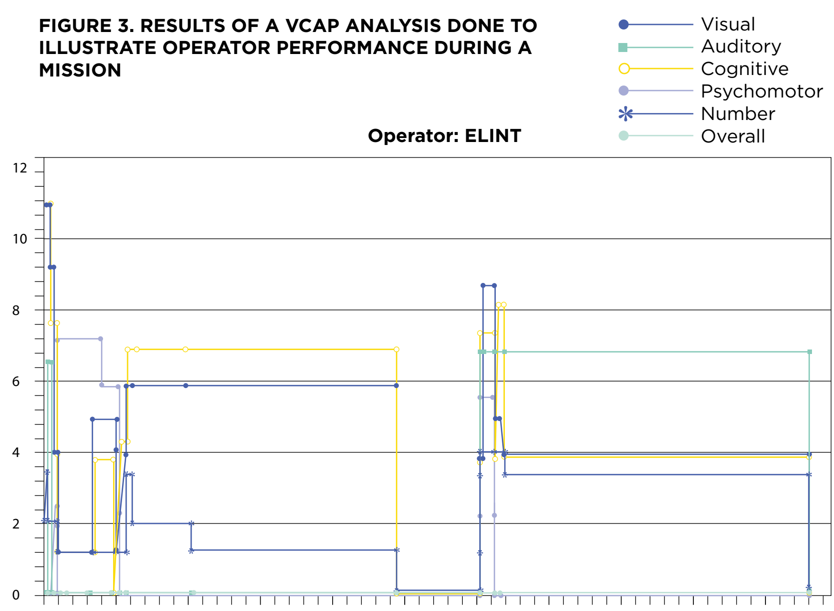
In this portion of the WLTA, the analyst is interested in the time spent on particular components of the overall mission. The results from this analysis can be an indication of the complexity of the task or performance inefficiencies (e.g., poor system design, lack of training, etc.). Depending on the analyst's interpretation of the cause of the time spent on certain components of an overall mission, targeted training-related solutions may be identified.

Several options are available to gather time-estimate data. Ideally, the collection of time data should come from direct observation of actual operators performing the tasks during a live mission or on a simulator during a training exercise. In many cases, however, this is not possible, especially if the weapon system has not been built or the nature of the tasks do not allow for direct observation during a mission. As an alternative to observation, domain SMEs provide estimates of the amount of time spent performing each task, as well as whether each task is continuous (no observable start or end point) or discrete (actions with definite, observable start-end points). Prior to the SMEs providing these ratings, they are provided examples of discrete (e.g., manipulating a knob on a computer console) and continuous (e.g., monitoring targets on a radar screen) tasks. These tasks are graphically illustrated on flowcharts that clearly depict what is actually being done by an operator in response to a specific cue. The flowcharts make it easier to estimate the time it takes to accomplish a specific task, and provide analysts with both an average time on each discrete task and a range of time for the continuous tasks.

Information Processing Estimation

The next step of the WLTA is to determine and categorize the amount of workload required to perform the task during a typical mission. This step is likely the most challenging as it requires the analyst to implement a modeling approach that accounts for tasks occurring simultaneously, the types of tasks being done, and other factors that may shape the performance of the operator. Research suggests that humans are able to process information across multiple different VACP channels, as illustrated in Christopher D. Wickens' Multiple Resource Theory model (Wickens, 2002; Wickens, Sandry, & Vidulich, 1983). In such cases, the summative workload demands of multiple, simultaneous tasks on one channel can provide some indication of the likelihood an individual would be able to perform two or more tasks at the same time with a given workload. For example, if a task calls for an operator to simultaneously aim a weapon at a target (rated a 4 on the visual channel by the operator) and make some fine discrimination of symbols on a screen (rated a 5 on the visual channel), the combined demand on the operator's visual channel would exceed the highest rating possible on the visual scale (see Appendix). This high-workload rating on the visual channel would be cause for concern in a design that required an operator to simultaneously perform these two tasks. The VACP scales are provided in the Appendix.

FIGURE 3. RESULTS OF A VCAP ANALYSIS DONE TO ILLUSTRATE OPERATOR PERFORMANCE DURING A MISSION



Note. ELINT = Electronics Intelligence.

From a training analyst perspective, it is necessary to assess the workload demands on an operator at different intervals throughout the mission. To do so, the VACP components of the tasks have to be estimated (McCracken & Aldrich, 1984; Szabo & Bierbaum, 1986) and populated into a discrete-event simulation/modeling software tool. A number of commercial and government discrete-event simulation/modeling software tools (e.g., MicroSaint, Improved Performance Research Integration Tool [IMPRINT]), are available to provide the capability to account for operator ability to multitask across noncompeting processing channels consistent with Wickens' Multiple Resource Theory (Wickens, 2002; U.S. Army Research Laboratory, 2005). Figure 3 provides an example of a simulation showing how operators reacted to a surveillance mission situation. It uses the dynamic modeling technique of Coloured PetriNet (Kristensen, Christensen, & Jensen, 1998) to illustrate the predicted VACP demands on an electronic intelligence (ELINT) operator in a surveillance aircraft while performing assigned tasks in a specified period of time during an operational mission. Careful evaluation of these workload predictions provided the analyst with insight on candidate tasks where workload demands may be improved. For example in Figure 3, the data indicate that about 7 minutes into the mission, the operator had to undertake several tasks while responding to target cues at the workstation. During 30-second intervals, the operator had to simultaneously employ several skills, which caused a temporary visual and cognitive overload. The operator used high visual skills (shown by blue line showing 8.5—exceeding the visual workload scale). Thus, the operator may not have been able to "see" all the target data available on the screen during that 30-second interval. The operator also used high cognitive skills to interpret what was being seen and heard (shown by green line showing 8.3—exceeding the cognitive workload scale). Thus, the operator may not have been able to comprehend the information presented. Both of these were done while interpreting sound patterns (shown by red line indicating 7.0 on the auditory scale) and manually adjusting a thumbwheel (shown by the light blue line indicating 5.8 on the psychomotor scale). This "task-stacking" situation resulted in the operator exceeding visual and cognitive capacity for approximately 30 seconds, meaning critical information may have been missed, which could impact overall mission performance. With this information, the engineers, human factors psychologists, and instructional system designers can begin to develop alternatives for task redesign, human engineering improvements, and/or training solutions. In the following section, a few examples of this process are provided.

Workload Solution Identification

The risk in developing weapon systems without significant consideration for how the operator will actually utilize them is that the system utilization may fall significantly below its potential. Additionally, a great deal of time and resources may be required in developing training systems for the operator. Utilizing WLTA data up front may prevent this situation. Workload solutions can take many forms, and should be based on the cost, schedule, and performance considerations by the weapon systems program. The final solution(s) chosen should be guided, at least in part, by the results from the WLTA. For purposes of this article, only training solutions are discussed, but WLTA identifies where workload issues may arise within a mission scenario for operators of a system and narrows the focus to particular tasks and combinations of tasks.

WLTA provides information about the operator tasks and provides the training developer with data about how user interfaces are structured to enable performers to effectively use the weapon system. Specifically, WLTA uncovers cues that initiate task behaviors, the time required to perform the tasks, and documents various demands the tasks place on the individual. Engineers in the design of weapon systems can use this information in the design of the weapon system. For example, in the ELINT operator example, a software modification can allow the workstation to "automatically identify" targets, thus relieving the operator from the requirement to visually identify the target. This information helps the training analyst establish a training strategy to support successful accomplishment of the task. For this reason, two training-focused performance solutions that can be identified and implemented based on the WLTA data are *what to train* and *how to train* specific tasks. A third training solution that can be derived from WLTA data is *error reduction*. Each potential solution will be discussed in turn.

What to Train

The benefit of the information provided by the WLTA is that it tells training analysts where operators may spend most of their time and what tasks require the most of the operator's limited resources during a mission. The analysts can then dig deeper into this information to understand whether these are areas of training importance and then focus training on that area of tasks. In Figure 4, a decision-making matrix that could be used by instructional systems developers to focus training is provided. In this contrived example, reasonable tradeoffs of what to train can be made to focus on tasks that require High Information Processing (I and III) because operators are likely to require the most support in performing the tasks.

Tasks requiring a High Time Spent but Low Information Processing (II) can then be assessed to determine whether these are tasks that could be automated or distributed to other team members to allow more time for operators to perform I and III tasks. Finally, tasks within the IV quadrant may be identified as unnecessary to train, thereby assisting the IPT in allocating resources for the best return on investment. It should be noted that this decision-making matrix is intentionally simplistic for the purposes of this article. Factors such as the criticality of the tasks, number of information processing channels required, and others important to the weapon system should also be considered in determining what to train. In the ELINT operator example, an early decision to fund a software modification to "automatically identify" targets can provide life-cycle cost reductions from a training perspective. Since targets will be "automatically identified" by the workstations, then training objectives relating to interpreting the information will be incorporated in the curriculum. Without the need to teach how to manually recognize the targets, the course can be shortened, reducing the overall life-cycle training costs.

FIGURE 4. DECISION-MAKING MATRIX TO GUIDE TRAINING

	High Information Processing	Low Information Processing
High Time Spent	I	II
Low Time Spent	III	IV

How to Train

Once decisions are made regarding what to train, instructional systems specialists can also utilize WLTA results to determine how best to train the skills that are identified as training tasks. For tasks that fall within the II and IV quadrants of Figure 4, low information processing is required, suggesting that these tasks are relatively automatic or simplistic. This suggests that these types of skills may be most effectively taught partly through training methods such as computer-based online courses and partly through task training devices or training simulators, wherein trainees receive a demonstration of how/when to perform the tasks and opportunities to practice performing the skills. Conversely, demanding tasks (i.e., high information processing tasks [I and III]) often involve more cue complexity and mental effort (Wickens & Carswell, 2006). With this information in hand, the instructional developer can appropriate more time to train complex tasks and ensure prerequisite knowledge and skills are acquired early in training. Furthermore, training strategies can be chosen to ensure more trainee-instructor interaction, and may allow operators repeated opportunities to practice

the tasks with varying and increasing levels of complexity to build the decision-making and information processing skills that are less outwardly tangible and difficult to train.

Reducing Errors

Interviews with SMEs during the WLTA often reveal common mistakes (as well as their consequences) made by operators. Senior operators will comment that mistakes in performance are usually traceable to inattention, over attention, or fixation (Greenwell, Strunk, & Knight, 2004; Wickens & Carswell, 2006). As Carl (2009, p. 120) noted, "…there is a tendency for performers to devote too much time to some cues, devote too little time to other cues, or poorly manage their time in attending to all the cues that impact task execution." With this information, instructional designers can focus on initially training new operators to select and concentrate on important task cues while disregarding irrelevant noise. In this case, utilizing WLTA data will not only emphasize the important components of training, it will reduce downstream performance problems that will increase life-cycle costs for repair or replacement of the system. In the ELINT operator example, the costs for a software modification to "automate target recognition" are incurred only once during acquisition (unless there are system upgrades in which additional costs will be incurred). Training costs associated with teaching target recognition will reoccur with each new set of trained operators, thus affecting overall life-cycle training costs.

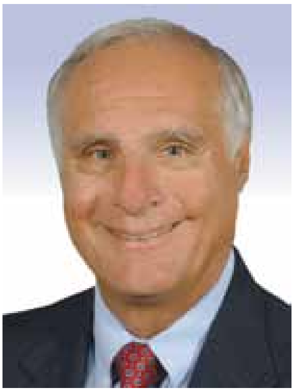
Conclusions

Although acquisition professionals are continually asked to identify tradeoffs to reduce weapon system budgets, tools are available to help them make decisions regarding life-cycle costs. Everyone acknowledges that weapon systems being acquired today are extremely sophisticated. The operator and maintainer tasks associated with the weapon systems are also becoming increasingly complex, and they require time and expensive simulators to satisfy training requirements. Training time and training media are quite costly from a life-cycle perspective.

WLTA could be an extremely valuable tool in reducing life-cycle costs, ensuring the system can be used effectively by designing training that can support the operator. Admittedly, WLTA is no simple task, requires significant time and support from the acquisition team, and must be adapted to the needs of the individual program. However, the results of WLTAs can become increasingly valuable as the team is required to make trade-off decisions and must negotiate

with program managers to retain funding, which can be done with the support of systematically derived evidence of how performance and mission requirements will be affected by design decisions.

Author Biographies



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APPENDIX

Visual Workload Scale	
Scale Value	**Visual Scale Descriptor**
0.0	No Visual Activity
1.0	Visually Register/Detect (detect occurrence of image)
3.7	Visually Discriminate (detect visual differences)
4.0	Visually Inspect/Check (discrete inspection/static condition)
5.0	Visually Locate/Align (selective orientation)
5.4	Visually Track/Follow (maintain orientation)
5.9	Visually Read (symbol)
7.0	Visually Scan/Search/Monitor (continuous/serial inspection, multiple conditions)

Auditory Workload Scale	
Scale Value	**Auditory Scale Descriptor**
0.0	No Auditory Activity
1.0	Detect/Register Sound (detect occurrence of sound)
2.0	Orient to Sound (general orientation/attention)
4.2	Orient to Sound (selective orientation/attention)
4.3	Verify Auditory Feedback (detect occurrence of anticipated sound)
4.9	Interpret Semantic Content (speech)
6.6	Discriminate Sound Characteristics (detect auditory differences)
7.0	Interpret Sound Patterns (pulse rates, etc.)

Cognitive Workload Scale	
Scale Value	**Cognitive Scale Descriptor**
0.0	No Cognitive Activity
1.0	Automatic (simple association)
1.2	Alternative Selection
3.7	Sign/Signal Recognition
4.6	Evaluation/Judgment (consider single aspect)
5.3	Encoding/Decoding, Recall
6.8	Evaluation/Judgment (consider several aspects)
7.0	Estimation, Calculation, Conversion

Psychomotor Workload Scale	
Scale Value	**Psychomotor Scale Descriptor**
0.0	No Psychomotor Activity
1.0	Speech
2.2	Discrete Actuation (button, toggle, trigger)
2.6	Continuous Adjustive (Flight control, sensor control)
4.6	Manipulative
5.8	Discrete Adjustive (rotary, vertical thumbwheel, lever position)
6.5	Symbolic Production (writing)
7.0	Serial Discrete Manipulation (keyboard entries)


Training
Task
analysis
function
analysis

The Defense Acquisition Professional Reading List

The Defense Acquisition Professional Reading List is intended to enrich the knowledge and understanding of the civilian, military, contractor, and industrial workforce who participate in the entire defense acquisition enterprise. These book reviews/recommendations are designed to complement the education and training that are vital to developing the essential competencies and skills required of the Defense Acquisition Workforce. Each issue of the *Defense Acquisition Research Journal (ARJ)* will contain one or more reviews of suggested books, with more available on the *ARJ* website.

We encourage *ARJ* readers to submit reviews of books they believe should be required reading for the defense acquisition professional. The reviews should be 400 words or fewer, describe the book and its major ideas, and explain its relevance to defense acquisition. Please send your reviews to the Managing Editor, *Defense Acquisition Research Journal*:
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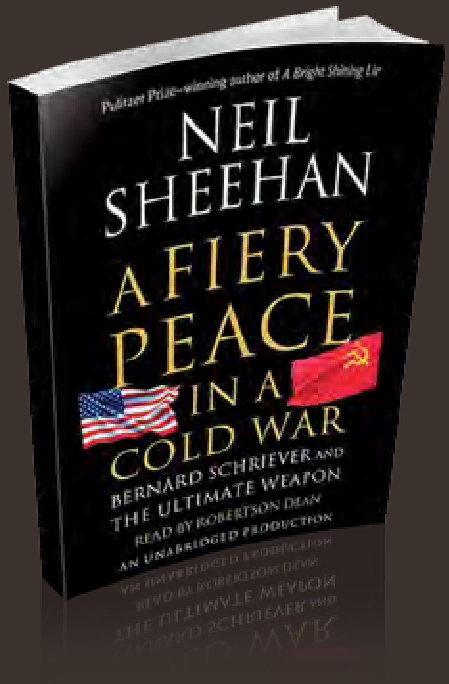

Book Reviewed:
A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon
Author(s):
Neil Sheehan
Publisher:
New York, Random House
Copyright Date:
2009
ISBN:
0679422846
Hard/Softcover:
Hardcover: 560 pages
Reviewed by:
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Review:

With an attention to detail seldom encountered, coupled with penetrating psychological explorations into the minds and motives of many of those involved, Pulitzer prize winning author Neil Sheehan provides a comprehensive look at the Cold War development of the Intercontinental Ballistic Missile (ICBM), written around the story of the life and career of Gen. Bernard Schriever, commander of the Air Force Systems Command, the brilliant man who brought the ICBM to life. He does this while exploring the birth of the United States Air Force and the formation of the Strategic Air Command. The importance of the ICBM among U.S. weapon systems, and how the people involved came together to give it birth, is masterfully recounted.

Schriever's influence was palpable. He had battled the likes of Curtis LeMay, first commander of Strategic Air Command, who believed bombers were the ultimate strategic weapon. Sheehan shows how they lacked the vision to see how useless bombers would be in the event of a strategic nuclear war where the ICBM, capable of striking a target continents away in a matter of minutes, would be the primary—and deciding—weapon. By 1963, Schriever controlled 40 percent of the Air Force budget.

Sheehan captures in fascinating detail the relationship between Schriever and the head of the U.S. Army Air Force, Henry "Hap" Arnold, and shows with clarity seldom seen elsewhere the influence a visionary leader like Arnold is able to exert to shape the career and open the doors to advancement of someone as brilliant and visionary as Schreiver. He shows how Schriever's vision and strategic thinking ability enabled him to see with absolute clarity the need to develop the ICBM to protect his adopted country from the growing menace of the Soviet Union, in spite of encountering resistance from LeMay at every turn. Sheehan also describes how Schriever set up research and development labs as a critical element in the advancement of weapon systems, while addressing the problems with Soviet spies who had infiltrated the research labs. He was able to stay on target, to continually shift tactics to reach his strategic goal, working through and around challenges from people, budgets, family obligations, and Air Force top brass.

All those who worked with Schriever really did walk with a legend whose story deserved to be memorialized. For this, we owe Sheehan a debt of gratitude.

RECOGNITION OF REVIEWERS FOR PRINT YEAR 2011

In this issue, we would like to take the opportunity to thank each individual who has contributed to the *Defense Acquisition Research Journal* by participating in the peer-review process. The assistance of the subject matter experts listed below provided impartial evaluation of the articles published in the journal for Issues 57–60. In addition, we would like to thank those who indicated that they prefer to remain anonymous. We appreciate your integral contributions to our process.

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Research involves the creation of new knowledge. This generally requires using material from primary sources, including program documents, policy papers, memoranda, surveys, interviews, etc. Articles are characterized by a systematic inquiry into a subject to discover/revise facts or theories with the possibility of influencing the development of acquisition policy and/or process.

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The readers of the *Defense ARJ* are primarily practitioners within the defense acquisition community. Authors should therefore strive to demonstrate, clearly and concisely, how their work affects this community. At the same time, do not take an overly scholarly approach in either content or language.

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